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# MEASURES OF MEMORY

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We review here a body of work that is at once a natural outgrowth of a hundred years' empirical research on human memory and a revolution in the

way we measure and interpret the influence of past events on current experiences and behavior. The crucial research tool consists of examining interrelationships among different memory measures, a technique we refer to as *task-comparison methodology*.

There is nothing new in task-comparison methodology, per se. Comparisons between traditional free recall, cued recall, and recognition measures fueled theoretical developments in the 1970s; and, in an earlier era, comparisons of cued recall, modified-modified free recall, and matchingrecognition were central to theories of interference. What *is* new, and critical to the work we review here, is that task comparisons have been extended to include a new set of measures that differ markedly from traditional measures in the demands they make on the subject and in the picture they provide of the impact of a prior episode.

### FORMS OF MEMORY AND METHODS OF TESTING

Although the relationships between cued recall, free recall, and recognition are highly complex, these three memory tests share an essential property: Success in them is predicated upon the subject's knowledge of events that occurred when he/she was personally present in a particular spatiotemporal context. Because the task instructions make explicit reference to an episode in the subject's personal history, such tasks have been referred to as *autobiographical* (Jacoby & Dallas 1981), *direct* (Johnson & Hasher 1987), *episodic* (Tulving 1972, 1983), *explicit* (Graf & Schacter 1985; Schacter 1985a,b, 1987), or *intentional* (Jacoby 1984) memory tests.

These traditional measures of memory do not, however, exhaust the possible memorial manifestations of personal experiences. Another set of tasks, classified as implicit (Graf & Schacter 1985; Schacter 1985a,b, 1987), indirect (Johnson & Hasher 1987), or incidental (Jacoby 1984) tests of memory, involve no reference to an event in the subject's personal history but are nonetheless influenced by such events. For example, prior experience with a particular word might later improve a subject's ability to identify that item under conditions of perceptual difficulty, restore deleted letters in order to complete that item, or make a decision concerning that item's lexical status. In general, such tasks require the subject to demonstrate conceptual, factual, lexical, perceptual, or procedural knowledge, or to make some form of affective or cognitive judgment. The measures of interest reflect change in performance (e.g. change in accuracy and/or speed) as a function of some form of prior experience (e.g. experience with the task, with the test stimuli, or with related stimuli). When the prior experience occurs within the experimental context, it is possible to compare such measures of behavioral change with traditional measures of memory for the events causing that change.

The extension of task-comparison methods to encompass measures of behavioral change has generated considerable excitement in the field, largely because a number of striking dissociations between these measures and traditional measures have been demonstrated. For example, behavioral change caused by an event is sometimes observed in the absence of the ability to recall or recognize that event as having occurred. The occurrence of such dissociations permits the minimal conclusion that the two types of measure can reveal different aspects of memory function: Measures to support Ebbinghaus's claim that prior episodes can "give indubitable proof of their continuing existence even if they themselves do not return to consciousness at all" (1885/1964, p. 2).

The underlying assumption of task-comparison methods is that different tasks make different informational demands on the subject. Based on patterns of dissociations and parallel effects across tasks as a function of critical independent variables, inferences can be made about the similarities and differences between the mental states and processes necessary to comply with the informational demands of the respective tasks. This methodology is therefore central to one of the fundamental aims of cognitive science—to determine how much heterogeneity in mental structures and processes is necessary to account for the complexity of experience and behavior.

The potential payoff of this new application of task-comparison methods is, from a theoretical standpoint, enormous. In the limit, it may prove possible to integrate theories of encoding, storage, and retrieval of personal experiences with theories of organization and retrieval of knowledge (i.e. conceptual, factual, lexical, perceptual, and procedural knowledge). These cognitive subareas have traditionally remained somewhat separate, each being associated with a particular set of paradigms and associated theoretical constructs.

### Direct and Indirect Measures

Here we adopt Johnson & Hasher's (1987) use of the terms *direct* and *indirect* to characterize the two classes of memory measures outlined above. As we define them, these terms classify memory tests with respect to task instructions and measurement criteria. The direct/indirect nomenclature therefore involves minimal a priori assumptions concerning the mental states and processes involved in performing the tasks.

DIRECT MEMORY TESTS We define as *direct* those tasks in which the instructions at the time of the memory test make reference to a target event (or target events) in the personal history of the subject (e.g. by mentioning the spatiotemporal context—time of day, date, environment—in which the event occurred). The subject is deemed successful in such tasks when she/he gives behavioral evidence of knowledge concerning that event. A typical target

event is the presentation of a list of words, pictures, or sentences, although it could be an event in the subject's preexperimental personal history. In a recognition test, the subject is required to discriminate stimuli that were present during the target event from stimuli that were not present. In recall tests, the subject is required to produce—with or without the aid of cues—items that formed part of the target event. When cues are presented at test, they might form part of the stimuli presented during the target event (*intralist cues*—e.g. Nelson & McEvoy 1979b; Tulving & Thomson 1973), or they might be *extralist cues* that are related in some way to the target item (semantically—e.g. Nelson & McEvoy 1977b; Thomson & Tulving 1970; phonemically—e.g. Blaxton 1985; Nelson & McEvoy 1979b; Roediger & Blaxton 1987a).

INDIRECT MEMORY TESTS We define as *indirect* those tests requiring the subject to engage in some cognitive or motor activity, when the instructions refer only to the task at hand, and do not make reference to prior events. The measures of interest reflect a change (typically a facilitation) in task performance observed by comparing performance with relevant prior experience to performance without such experience (a control condition). The term *indirect* is particularly suitable because the relevant tasks do not "direct" the subject at a target event, and because it implies that such measures of memory are generally *derived* by comparing at least two separate data points. Indirect measures fall into four categories: (a) tests of factual, conceptual, lexical, and perceptual knowledge; (b) tests of procedural knowledge (i.e. skilled performance, problem solving); (c) measures of evaluative response; and (d) other measures of behavioral change, including neurophysiological response and conditioning measures.

*Conceptual, factual, lexical, and perceptual knowledge* Tasks in this category have traditionally been used by researchers attempting to specify structures and processes involved in the retrieval of permanent knowledge. In the factual and conceptual domains, subjects have been required to retrieve items of general knowledge (e.g. Blaxton 1985; Roediger & Blaxton 1987a; Roediger et al 1983), generate members of a semantic category (e.g. Brown 1981; Gardner et al 1973; Graf et al 1985; Kihlstrom 1980), generate associates to stimulus words (e.g. Chumbley & Balota 1984; Kihlstrom 1980; Schacter 1985a; Shimamura & Squire 1984), verify category membership (e.g. Balota & Chumbley 1984; Collins & Quillian 1970; Hampton 1984; Gruenenfelder 1986), and categorize or classify stimuli (e.g. Durso & Johnson 1979; Higgins et al 1985; Kroll & Potter 1984; Metcalfe & Fisher 1986). In the lexical domain, tasks include lexical decision (e.g. Scarborough et al 1977), word naming or pronunciation (e.g. Balota & Chumbley 1985; de Groot 1985;

Lupker 1984; Seidenberg et al 1984), word retrieval (generating a word from a definition—e.g. Bowles & Poon 1985; Brown 1979), word completion (producing a word that fits a three-letter stem—e.g. Graf et al 1982; Graf et al 1984), fragment completion (supplying deleted letters to complete a word e.g. Roediger & Blaxton 1987a,b; Tulving et al 1982; Squire et al 1987), and spelling of auditorily presented homophones (Eich 1984; Jacoby & Witherspoon 1982). Perceptual tasks include perceptual identification of words (e.g. Feustel et al 1983; Jacoby & Dallas 1981), pictures (e.g. Carroll et al 1985; Jacoby & Brooks 1984; Warren & Morton 1982), and faces (e.g. Bruce & Valentine 1985); picture naming (e.g. Brown 1981; Carroll et al 1985; Durso & Johnson 1979); and identifying fragmented pictures (e.g. Roediger & Weldon 1987; Warrington & Weiskrantz 1968; Weldon & Roediger 1987). A number of other perceptual tasks are summarized by Weiskrantz (1985).

In these types of task the measures of interest are accuracy, or latency of a correct response. Prior exposure to test stimuli generally increases accuracy and/or decreases latency, a phenomenon known as *direct* or *repetition priming* (Cofer 1967). In paradigms in which subjects are to generate any response they wish to the test stimulus (e.g. generating category members, generating associates to words, word completion, homophone spelling), prior study of items increases the likelihood that those items will be generated as responses at test.

Changes in test performance are also observed when information that is related to test stimuli is presented prior to test. The typical example is the decrease in lexical decision latency consequent on presenting associatively or semantically related words prior to the test stimulus, a phenomenon known as *associative* or *semantic priming* (e.g. Fischler 1977; Meyer & Schvaneveldt 1971). Effects of prior presentation of stimuli that are graphemically and phonemically related to test items have also been studied (e.g. Bowles & Poon 1985; Brown 1979; Evett & Humphreys 1981; Forster & Davis 1984; Feustel et al 1983; Hillinger 1980; Mandler et al 1986; Shulman et al 1978), as have effects of presenting morphologically related words (e.g. Fowler et al 1985; Henderson et al 1984; Kempley & Morton 1982; Murrell & Morton 1974; Stanners et al 1979; for a summary, Henderson 1985). *Indirect priming* is any change in performance resulting from the presentation of information related in some way (associatively, semantically, graphemically, phonemically, or morphologically) to test stimuli.

*Procedural knowledge* Studies of skill learning and problem solving typically examine changes in performance as a function of degree of practice with the task. Perceptual-motor tasks such as pursuit rotor and mirror drawing have been studied (for summaries see Baddeley 1982; Cohen 1984; Moscovitch 1982; Squire & Cohen 1984). However, of particular interest in the current context are studies of the development of cognitive skills, such as proofread-

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ing (e.g. Levy 1983; Levy & Begin 1984) and reading geometrically transformed text (e.g. Graf & Levy 1984; Horton 1985; Kolers 1979, 1985; Kolers & Roediger 1984; Masson 1986; Moscovitch et al 1986). Problem-solving tasks that have been studied include solving jigsaw puzzles (Brooks & Baddeley 1976), the Tower of Hanoi puzzle (Cohen 1984; Cohen & Corkin 1981; Cohen et al 1985; Simon 1975), and control tasks, such as learning a rule relating size of work force to factory production output (Berry & Broadbent 1984). Other problem-solving tasks are summarized by Moscovitch (1982) and Weiskrantz (1985).

*Evaluative response* A number of researchers have investigated effects of exposure to stimuli upon evaluative responses to those stimuli. The classic studies by Zajonc and coworkers show that exposure to stimuli increases affective preference for those stimuli (for a summary see Zajonc 1980; see also Gordon & Holyoak 1983; Johnson et al 1985; Mandler & Shebo 1983; Seamon et al 1984 for follow-ups). Cognitive judgments are also influenced by stimulus exposure; for example, prior exposure to statements (or components of statements) increases the rated truth of those statements (e.g. Bacon 1979; Begg et al 1985). Other types of cognitive judgment have been studied by Jacoby (1987), Lewicki (1986), and Mandler et al (1987), among others.

Other measures of behavioral change Effects of prior exposure to stimuli can be revealed in changes in physiological response, such as galvanic skin response (e.g. Rees-Nishio, cited in Moscovitch 1985) and event-related potentials (e.g. Rugg 1987). Conditioning measures, such as eye-blink conditioning (Weiskrantz & Warrington 1979), can also be included as indirect tests of memory; measurements of interest simply reflect acquisition of a behavioral response to an originally neutral stimulus. Similarly, Schacter & Moscovitch (1984) have argued that habituation and novelty-preference paradigms used in studies of infant memory "can be conceptualized in terms of facilitated processing of old (familiar) stimuli, rather than in terms of gaining access to information about the prior occurrence of the familiar stimulus in the experimental context" (p. 184). Finally, measures of savings in relearning repeated items (e.g. Ebbinghaus 1885/1964; Nelson 1978) qualify as indirect memory measures, under the assumption that subjects are merely told to learn a list at test, with no indication as to whether or not that list has been presented before.

### Explicit and Implicit Forms of Memory

Schacter's work (e.g. 1985a,b, 1987; Graf & Schacter 1985, 1987; Schacter & Graf 1986a,b) represents a major theoretical and empirical contribution to research comparing direct and indirect memory measures. His explicit/

implicit memory distinction is currently more widely used as a task taxonomy than is the direct/indirect distinction that we use here. However, we deviate from current usage because the terms direct and indirect clearly refer to tasks and methods of measurement; they do not lend themselves to use as labels for hypothetical forms of memory underlying test performance. We agree with Tulving (1985b) that it is not possible to define and classify memory tasks without making some minimal assumptions about the mental states of the subject. However, there is a fine but very important line between mental states whose involvement in a task can be reasonably assumed a priori, given that the subject understands the task instructions, and mental states whose involvement in a task must be ascertained empirically through the use of verbal reports and/or behavioral data.

The terms *implicit memory* and *explicit memory* can be used interchangeably to refer to tasks and methods of measurement, or to hypothetical forms of memory (where *form of memory* is a term descriptive of mental content) whose existence must be inferred from behavioral data. For example, Schacter (1985b) states that "implicit memory is revealed on tasks that do not require reference to a specific prior episode" (p. 353). This definition is a task-based one, similar to that for indirect measures given above. By contrast, Graf & Schacter (1985) state that "implicit memory is revealed when performance on a task is facilitated in the absence of conscious recollection" (p. 501). This definition implies that implicit memory is *inferred* from a dissociation between two measures of memory; implicit memory, in this sense, is a term referring to a hypothetical form of memory (where "hypothetical" simply means "not directly observable").

Similarly, direct memory tests have been defined as "requiring conscious recollection of previous experiences" (Graf & Schacter 1985, p. 501) and requiring "conscious awareness of the learning episode for successful performance" (Roediger & Blaxton 1987a, p. 351). "Conscious recollection" or "awareness" can be taken as implying (a) awareness, based on task instructions, that the test refers to a prior episode and consequent intention to retrieve material from that episode, or (b) that the subject has a particular form of subjective awareness of the episode (e.g. reexperiencing the episode) in performing the task successfully. Once again, the former of these definitions is task-based, whereas the latter refers to mental states whose existence must be inferred from data.

It might be argued that the logical distinctions we make are too fine to be of empirical importance. However, there are at least four important negative consequences of using the terms explicit and implicit memory to refer to both tasks and hypothetical forms of remembering:

1. If direct memory (i.e. intentional retrieval of material from a prior event) is conflated with explicit memory (i.e. a form of subjective awareness

of a prior event), we definitionally rule out cases in which a subject becomes aware of a prior event without having consciously intended to do so. Such cases of *involuntary explicit memory* (Schacter 1987) were noted by Ebbinghaus (1885/1964), who pointed out that "mental states once present in consciousness return to it with apparent spontaneity and without any act of the will; . . . we at once recognise the returned mental state as one that has been previously experienced" (p. 2). The conflation of intentional retrieval and awareness of remembering in current memory studies has obscured the possible role of involuntary explicit memory in performance on indirect tests of memory (as noted by Schacter 1987).

2. Unwarranted assumptions are often made about the mental states or processes involved in performing a task. This difficulty is particularly acute in the case of direct memory measures. Of course, the task instructions in such tests refer to a prior episode; if the subject understands the instructions he/she is "aware of the prior episode" in the sense of being aware that the study episode occurred, and that she/he must recall or recognize material presented as part of that episode in order to achieve success in the task. However, these minimal assumptions about the task leave considerable slack with respect to the states of consciousness and memory processes involved in achieving success at the task: For example, it is well known that direct test performance involves a blend of reproductive and constructive, semantically based processes. Correct performance on a test of "conscious" memory therefore does not require as a precondition that the subject is conscious of the learning episode in the sense of reexperiencing that episode. For example, repeating an item results in improved free recall of that item but poorer memory for the specific details of that item's individual presentations (Watkins & Kerkar 1985). Similarly, Cermak (1984; Cermak & O'Connor 1983) argues that one amnesic's memory for his personal history represents "retrieval from a very personal base of semantic knowledge" (1984, p. 57); Brewer (1986) distinguishes between personal memory, autobiographical fact, and generic personal memory; and Tulving (1985c) distinguishes direct memory performance based on "remembering" versus "knowing" that an item was on a list of words. A review of contributions to Rubin's (1986) volume Autobiographical *Memory* confirms our conclusion concerning the complexity of the experiences and mental processes involved in direct tests. By ignoring this complexity, we limit our ability to interpret empirical relationships between direct and indirect measures.

3. It is sometimes assumed that a particular method of testing reveals only one underlying form of memory, and that different methods of testing necessarily reveal different forms of memory. For example, with reference to direct and indirect tests, Graf & Schacter (1987) state that they "have used the labels explicit and implicit to describe the forms of memory indexed by these two types of tests" (p. 45). This assimilation of forms of memory to methods of testing cannot be justified: The hypothesis that different testing methods reveal different forms of memory can be entertained only when *dissociations* between those methods of measurement are observed (Schacter 1985b). However, our review below shows that direct and indirect measures are sometimes influenced similarly by variables of interest. In these cases, we cannot be sure (a) whether two fundamentally different underlying forms of memory are affected similarly by a particular variable, or (b) whether the same form of memory is being engaged by both types of task. Distinguishing between these alternative explanations of parallel effects is a matter of considerable theoretical importance.

4. Confusion results when researchers suggest that performance on implicit memory tasks can be mediated by explicit remembering. For example, Schacter (1985b) argues that "there are two distinct ways to perform word completion tasks, one of which is independent of the capacity for explicit recollection and one of which makes use of this capacity" (p. 359). On the task-based definition of implicit memory, of course, this suggestion embodies a contradiction, because "implicit memory" refers to a facilitation in task performance regardless of the cause of such facilitation; the suggestion only makes sense when "explicit remembering" is taken as referring to a hypothetical form of memory that can manifest itself in both explicit and implicit memory tasks.

In this context it is also worth considering that implicit or less aware memory processes could influence performance on direct tests of memory: For example, Lockhart et al (1976) argue that effects of prior events are revealed in the way probe items are encoded, or interpreted, in a recognition memory test, and that such encoding processes are critical in determining the success of recognition attempts. A related proposal (Jacoby 1987; Jacoby & Brooks 1984; Jacoby & Dallas 1981; Johnston et al 1985; Masson 1984) is that subjects are led to attribute "oldness" to recognition probes when encoding of those probes is facilitated by implicit memory processes. In memorydisordered subjects, cued recall performance is much better when to-beremembered response words are semantically related to the stimulus words than when they are unrelated (e.g. Graf & Schacter 1985; Schacter 1985a; Shimamura & Squire 1984; Winocur & Weiskrantz 1976). Despite the fact that cued recall is a direct memory test, the advantage for pairs whose members are related has been attributed to implicit memory; presentation of a related pair at study is assumed to prime the pair as a unit, increasing the probability that the unit will be redintegrated given a partial cue (Graf et al 1984; Mayes et al 1987; Schacter 1985a; Shimamura & Squire 1984).

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### A Taxonomy of Forms of Memory and Methods of Testing

The above considerations suggest that distinctions between tasks must necessarily be made independently of distinctions between hypothetical forms of memory. In the current article we use the terms *direct* and *indirect* to distinguish memory tests, based on instructions and method of measurement; we use the terms *implicit* and *explicit memory* to refer to the effects of an episode that are expressed without awareness of remembering, and with awareness of remembering, respectively. Following Ebbinghaus (1885/1964) and Schacter (1987), explicit memory can be intentional or involuntary: Reexperiencing of an episode, or reconstruction of its contents, that occurs as a result of a conscious, strategic attempt to remember that episode is termed intentional explicit memory; reexperiencing or reconstruction of an episode that occurs spontaneously is termed involuntary explicit memory. Our view of the relationship between measures of memory and forms of memory is summarized in Table 1. The cells of the table indicate the relative frequency with which a given form of memory is involved in a particular type of test, based on the evidence reviewed here. Because the pattern of mnemonic performance across direct and indirect tests differs so markedly between amnesic and normal subjects (as reviewed below), we treat these categories of subject separately.

Type of test (Type of subject)	Explicit: intentional	Explicit: involuntary	Implicit	
Direct		1770		
(normals)	always	occasionally? <sup>a</sup>	sometimesb	
(amnesics)	sometimes <sup>c</sup>	occasionally? <sup>c</sup>	sometimesd	
Indirect				
(normals)	sometimese	sometimesf	usually	
(amnesics)	never	never	· always	

Тa	able 1 Fro	equen	cy with	whi	ch a give	en fori	n o	f memor	ry co	ntributes
to	performan	ice in	direct	and	indirect	tests	of	normal	and	amnesic
su	bjects									

<sup>a</sup> As in hypermnesia (Erdelyi & Becker 1974).

<sup>b</sup>As in the influence of implicit memory on encoding of recognition probes (e.g. Lockhart et al 1976; Jacoby & Dallas 1981).

Depending on factors such as severity of amnesia and difficulty of test.

<sup>d</sup> As in cued recall with pairs whose members are related, where good performance in amnesics can be attributed to an implicit priming effect (Graf et al 1984; Schacter 1985a; Shimamura & Squire 1984; Winocur & Weiskrantz 1976).

e As when subjects spontaneously treat an indirect memory test, such as word completion, as a direct memory test.

<sup>f</sup> As when identification or generation of an item is followed by recognition of that item as having occurred previously.

### THEORETICAL APPROACHES

There has been general agreement that some type of classificatory distinction between forms of memory is necessary, such as the distinction between memory with and without awareness (Jacoby & Witherspoon 1982) or the distinction between implicit and explicit memory (Graf & Schacter 1985). Schacter (1987) finds a number of precedents for the distinction between implicit and explicit forms of memory in philosophy, neurology, psychology, and psychical research, dating as far back as Descartes. In another historical survey, Herrmann (1982) found 34 precedents for a distinction between memory for personal experiences and other forms of memory such as habits, skills, and general knowledge (for a similar survey and a modern approach to classification, see Brewer & Pani 1983). Modern research confirms the validity of such typologies by demonstrating dissociations between direct and indirect measures of memory.

While agreeing that there are different forms of memory, theorists disagree concerning the degree of heterogeneity in memory structures and processes necessary to explain these forms. We identify three general approaches to the relationship between less aware, or implicit, and more aware, or explicit, forms of memory.

### Abstractionist Positions

Abstractionist positions view implicit memory as reflecting modification of the state of abstract lexical, semantic, or procedural knowledge structures; by contrast, explicit memory is assumed to depend on formation and retrieval of memory traces representing specific experiences. Abstractionists are often neuroscientifically oriented, using brain lesion data to constrain their theories. Of particular interest are findings that amnesic patients are selectively impaired on direct tests of memory but show normal learning as measured by some indirect tests (reviewed below). These deficits are ascribed to an impairment of the system responsible for memory of specific experiences. In neuroscience, modularity of systems is the rule rather than the exception: If one accepts a straightforward relationship between brain systems and cognitive systems, the hypothesis of multiple memory systems is a logical extension of current knowledge (Cohen 1984; Oakley 1983; for discussion, see Cohen 1985; Olton 1985; Schacter 1986).

Tulving's (1972) heuristic distinction between *episodic* and *semantic* forms of memory was later developed into a multiple-system theory (Schacter & Tulving 1982a,b; Tulving 1983, 1984a). Episodic memory "deals with unique, concrete, personal, temporally dated events," while semantic memory "involves general, abstract, timeless knowledge that a person shares with others" (1986, p. 307). In recent versions of the theory (Tulving 1984b,c;

1985a,b,c; 1986) episodic memory is viewed as a specialized subsystem of semantic memory, with both systems embedded within a procedural memory, an arrangement Tulving terms *monohierarchical*. This position was designed to facilitate conceptualization of Tulving's (1983) hypothesis of the phylogenetic evolution of episodic from semantic memory, and to account for recent arguments that whereas indirect memory measures reveal evidence of memory early in human ontogeny, the capacity to perform direct memory tasks first emerges only at 8–9 months of age (Schacter & Moscovitch 1984).

There are a number of other multiple-system formulations that are somewhat analogous to the episodic-semantic distinction (e.g. Halgren 1984; Johnson 1983; Oakley 1983; O'Keefe & Nadel 1978; Olton et al 1979; Schacter & Moscovitch 1984; Warrington & Weiskrantz 1982). One of these deserves special note: Morton's (1969, 1970, 1979, 1981) multisystem theory differs from Tulving's in that conceptual and factual knowledge, as well as personal or episodic memories, are dealt with by the same system (the *cognitive system*); a separate system contains abstract representations for words (*logogens*) that are responsible for lexical access.

Other theorists regard the distinction between procedural and declarative (or propositional) memories (accepted by Tulving) as sufficient to explain the observed dissociations between direct and indirect measures (e.g. Baddeley 1984; Cohen 1984; McKoon et al 1986; Squire & Cohen 1984). The procedural/declarative distinction was originally formulated by workers in artificial intelligence as a distinction between types of knowledge (e.g. Barr & Feigenbaum 1981; Winograd 1975), but it has been extended into a multiplesystem viewpoint (Cohen 1984; Squire & Cohen 1984). Procedural memory involves "reorganization or other modification of existing processing structures or procedures," whereas declarative memory "represents explicitly new data structures derived from the operation of any process or procedure" (Cohen 1984, pp. 96-97). Although procedural memory can be revealed only when a task reengages prior processing operations, it is abstract in the sense that it does not record the specific prior events that caused those processing operations to be modified. The declarative system is considered to be responsible for conscious access to facts and past experiences; it is necessary for performance of direct memory tests, and is impaired in amnesia. An approach analogous to the procedural/declarative distinction is proposed by Mishkin (Mishkin et al 1984; Mishkin & Petri 1984), who distinguishes between a *memory* system and a *habit* system.

The distinction between *activation* and *elaboration* (Graf & Mandler 1984; Mandler 1980; Mandler et al 1986) is a process-oriented viewpoint; it differs from other abstractionist positions in being neutral with respect to the issue of memory systems. Activation of a preexisting mental representation "strengthens the relations among its components and increases its accessibility" (Graf & Mandler 1984, p. 553); elaborative processing is necessary in order to retain new relationships and relate stimuli to the context in which they were presented. Activation alone is sufficient to result in processing facilitation that is revealed in indirect memory tests, whereas elaboration is necessary for direct tests of memory. A similar concept of *trace activation* has been proposed by Diamond & Rozin (1984; see also Mortensen 1980).

### Nonabstractionist Positions

Nonabstractionists are unified by their disagreement with the necessity to distinguish abstract representations from memory traces that preserve information from specific experiences. They are typically mainstream cognitive psychologists who concern themselves primarily with the behavior of normal human subjects.

Kolers (e.g. 1979, 1985; Kolers & Roediger 1984; Kolers & Smythe 1984) has attacked the distinction between procedural and declarative (or propositional) knowledge, arguing that "statements or declarations . . . do not fail of procedural representation" (Kolers & Roediger 1984, p. 437). When a subject displays knowledge, he/she is assumed to be engaging in a form of skilled performance. Knowledge is regarded as being specific to the processes by which that knowledge is acquired: Rather than offering a "unitary" theory in opposition to multisystem approaches, Kolers suggests that mentation consists of a multiplicity of processes whose properties are poorly correlated. Memory is revealed to the extent that processing operations at study and test overlap (the principle of *transfer-appropriate processing*, Bransford et al 1979). Dissociations between direct and indirect measures of retention are to be expected when members of the two classes of task make different processing requirements, and not otherwise [see also Moscovitch et al (1986) for a similar viewpoint].

Jacoby (1983b), Blaxton (1985), and Roediger & Blaxton (1987a,b) have used the terms *conceptually driven* and *data-driven* as a taxonomy of the processing demands of memory tests. Direct memory tests typically involve more conceptually driven than data-driven processing because the subject uses associative information to reconstruct the study episode mentally; indirect memory tests typically involve more data-driven than conceptually driven processes because the subject focusses on external stimuli (e.g. a fragment of a word) at test. Dissociations between data-driven and conceptually driven memory tests would be expected as a function of the type of information (semantic-associative vs perceptual) encoded in a prior episode.

Jacoby (1982, 1983a,b, 1984, 1987; Jacoby & Brooks 1984; Jacoby & Dallas 1981; Jacoby & Witherspoon 1982) argues that implicit and explicit memory are reflections of "different aspects of memory for whole prior processing episodes" (1983a, p. 21). The aware and unaware aspects of

memory for episodes are assumed to result from differences in information provided by test cues, and possibly accompanying differences in retrieval processes (see Whittlesea 1987 for a similar position).

### Hybrid Positions

Like abstractionist positions, hybrid positions accept a distinction between abstract representations and memory traces preserving information about specific events. However, hybrid approaches assume that episodic memory traces can be accessed either explicitly/with awareness, or implicitly/without awareness. This dual-access assumption differentiates hybrid approaches from abstractionist views postulating that explicit, or strategically based, memory sometimes influences performance on indirect memory tests (e.g. Clarke & Morton 1983; Cohen 1984; den Heyer 1986; Diamond & Rozin 1984; Forster & Davis 1984; Fowler et al 1985; Graf et al 1984; Johnson et al 1985; Monsell 1985; Oliphant 1983; Squire et al 1987).

Feustel et al (1983) and Salasoo et al (1985) propose a model of perceptual identification in which both abstract lexical codes and episodic memory images contribute to identification. Presence of a lexical unit corresponding to a stimulus confers an advantage on that stimulus in identification; however, repetition priming effects are attributed to episodic images from prior presentations of items. As in Jacoby's view, different test cues result in different modes of access to the episodic information, permitting an accounting of dissociations between direct and indirect memory tests.

In contrast to Feustel et al, Schacter (e.g. 1985a,b, 1987) regards repetition priming as critically dependent on activation of unitized memory structures; however, he also proposes that newly acquired information influences the extent of priming, differentiating his view from simple activation views described above. To account for effects of newly acquired information on implicit memory, Schacter (1985a) proposes that unitized structures can be *locally modified* by the episodic contexts in which they occur. By contrast, explicit memory for newly acquired information is supported by *nested* structures, which are accessible only through contextual cues. However, it is not clear whether this type of model is identifiably different from a modified version of the Feustel et al model in which implicit memory results either from activation of unitized structures or from implicit access to episodes, and explicit memory depends on explicit access to those same episodes.

### DISSOCIATIONS ACROSS MEASURES

A number of variables are strongly associated with performance on direct memory tests but are not associated with memory as revealed by indirect tests. As direct tests are held to reveal memory for past episodes, this evidence can be taken to suggest that indirect tests do not reflect memory for episodes; rather, they can be held to reflect alteration of the state of abstract and relatively stable lexical, semantic, or procedural memory structures. The validity and replicability of a number of dissociations of this type reported by Tulving (1983, 1984a) has been questioned by McKoon et al (1986; Ratcliff & McKoon 1986). While we can agree with McKoon et al that dissociations between direct and indirect measures are not a completely general phenomenon (as reviewed below), a more extensive review indicates that dissociations produced by a number of critical variables are rather stable across studies.

### Memory-Disordered Subjects

Chronic global amnesia is characterized by "a clinically significant deficit in new learning of verbal and nonverbal material irrespective of stimulus modality [that is] disproportionate to other cognitive impairment" (Corkin et al 1985, p. 10). Etiologies of organic amnesia include chronic alcohol abuse (Korsakoff's syndrome), bilateral resection of the medial temporal lobe (e.g. case H. M.), herpes simplex encephalitis, cerebral anoxia, closed head injury, ruptured aneurysm of the anterior communicating artery, and bilateral stroke. Studies comparing direct and indirect memory tests have used amnesics from all of these etiologic categories; other memory-disordered patients used in such studies include a nonglobal amnesic (case N. A.; Cohen & Squire 1980; Squire & Cohen 1982; Zola-Morgan et al 1983) with damage to the dorsomedial thalamic nucleus (and probably other structures, Weiskrantz 1985), patients receiving electroconvulsive therapy (ECT; e.g. Squire et al 1978, 1984, 1985), and patients with progressive dementia of Alzheimer's type (e.g. Martone et al 1984; Moscovitch et al 1986; Shimamura et al 1987).

A matter currently receiving intensive discussion is whether observed differences in memory performance across these categories of patient reflect fundamentally dissimilar memory deficits, or whether there is a core memory deficit differing in severity between patients, together with differences in superimposed nonobligatory intellectual deficits (e.g. Albert & Moss 1984; Corkin et al 1985; Mayes 1986; Morris & Kopelman 1986; Moscovitch 1982; Shimamura et al 1987; Squire 1982; Squire & Cohen 1984; Squire & Shimamura 1986; Weiskrantz 1985). This issue is beyond the scope of this paper; however, we note that results often differ across patient groups, so that comparisons across studies using different classes of memory-disordered patients must be made with caution.

Numerous studies have shown preserved memory in memory-disordered patients as indexed by indirect tests of memory (where "preserved" means "at a level not worse than controls") together with impaired memory as indexed by direct tests (where "impaired" means "at a level significantly worse than controls"). In addition, there are a number of more informal demonstrations

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of learning in amnesics (e.g. studies in which only one memory task was studied, or no control group was included). Reviews of this material are available (e.g. Baddeley 1982; Cohen 1984; Moscovitch 1982, 1984, 1985; Schacter 1985a,b, 1987; Schacter & Graf 1986b; Shimamura 1986; Squire 1986; Squire & Cohen 1984; Weiskrantz 1985) so we restrict ourselves to recent examples relevant to the theoretical discussion below.

SEMANTIC AND LEXICAL KNOWLEDGE In an extension of the classic studies by Warrington & Weiskrantz (1968, 1970, 1974, 1978) and Weiskrantz & Warrington (1970), Graf et al (1984) found normal priming effects in memory-disordered patients of various etiologies in the word-completion paradigm. In this paradigm the subject is asked to complete each of a list of three-letter word stems (e.g. REA\_\_\_\_\_) with the first English word that comes to mind; there are generally about ten appropriate completions. Prior study of a word significantly increased the probability of generating that word as a completion to the appropriate stem (relative to baseline words with no prior study). This priming effect was equivalent in amnesics and control subjects; additionally, the advantage for primed words declined over time at the same rate for both groups, being absent by about 2 hr after presentation. By contrast, when subjects were told to use the stems to retrieve study-list words (a direct memory test) amnesics were severely impaired relative to normals. A number of studies have replicated preserved priming of word completion in amnesics in conjunction with impaired performance on direct tests of memory (Diamond & Rozin 1984; Graf & Schacter 1985; Graf et al 1985; Shimamura & Squire 1984; Shimamura et al 1987; Squire et al 1987, Expt. 1).

Similar patterns of results have been found with a variety of other indirect memory tests. Gardner et al (1973) and Graf et al (1985) report that studying category exemplars enhanced the likelihood that those exemplars would be given in response to category cues in a generation task. This priming effect was equivalent in amnesic and control subjects; however, when asked to use category cues to retrieve studied words (Gardner et al 1973), or to freely recall studied words (Graf et al 1985), amnesics were impaired relative to controls. Shimamura & Squire (1984) found that study of a pair such as table-chair more than doubled the probability (relative to baseline) that the studied response (chair) would be given as a response to the stimulus (table) in a free-association test. Free-association priming was equivalent in Korsakoffs and controls, whereas Korsakoffs were impaired relative to controls on a cued-recall test with the same materials. Schacter (1985a) reports a similar dissociation in amnesics of diverse etiologies using idiomatic phrases such as sour grapes and small potatoes as the studied items. Moscovitch (1984, 1985) obtained normal repetition-priming effects in memory-disordered patients in a lexical-decision task, in conjunction with poor or chance performance on a recognition memory test. Cermak et al (1985, Expt. 1) found preserved priming in perceptual identification of words by Korsakoff patients, together with impaired recognition memory performance. Finally, Jacoby & Witherspoon (1982) had Korsakoff patients and controls spell auditorily presented homophones at test; some of these homophones had earlier been presented in a biasing context that required the least common of the two or more meanings of the homophone to be selected. Biased homophones were more likely than new homophones to be spelled according to their least common interpretation; this priming effect was larger for Korsakoffs than controls, whereas Korsakoffs were severely impaired relative to controls on a subsequent recognition memory test.

PROCEDURAL KNOWLEDGE The early literature demonstrated that amnesics could acquire and retain a number of perceptual-motor skills, such as pursuit rotor and mirror drawing, and show benefits of practice on problemsolving tasks, such as solving a jigsaw puzzle and learning a mathematical rule (for reviews: Baddeley 1982; Cohen 1984; Moscovitch 1982; Squire & Cohen 1984; Weiskrantz 1985). In the present paper we focus on indirect tests that are more amenable to comparison with direct memory measures.

An important property of studies of reading degraded or geometrically transformed script is that they permit general benefits from increased practice to be separated from specific benefits accruing to repeated groups of words or sentences (by comparison of repeated and nonrepeated items as practice progresses). Initial studies of speed of reading mirror-reversed script (Cohen & Squire 1980; Martone et al 1984) found a general practice effect in amnesics, as well as an item-specific repetition effect; however, whereas the general practice effect was preserved in amnesics, the item-specific effect was not as large in amnesics as in normals. This impairment was paralleled by the amnesics' impairment in recognizing old items.

Moscovitch et al (1986) argue that the impairment on repeated items occurred because the difficulty of reading mirror-reversed script encourages normal subjects to use explicit memory to speed reading of repeated items (for a similar argument see Horton 1985), a resource not available to the amnesic patients. In their Experiment 2, they used speeded reading of normally oriented masked words and sentences to reduce possible influences of explicit memory on reading speed; item-specific repetition effects were now preserved in a heterogeneous group of memory-disordered patients (including early Alzheimer's sufferers), whereas these patients were severely impaired on a recognition test for the same materials.

As in studies of normal subjects (e.g. Kolers 1976), practice effects in reading geometrically transformed text are quite durable in memory-

disordered patients: Moscovitch et al (1986, Expt. 1) found both general and item-specific effects at intervals from 4 days through 2 weeks following initial training, using sentences whose letters were rotated 180 degrees around their vertical axis. In Cohen & Squire (1980), both general and item-specific effects persisted at a delay of 3 months. Interestingly, mirror-reading skill acquired before a course of ECT treatments persisted after those treatments, despite retrograde amnesia for the words read during acquisition of the skill (Squire et al 1984).

A most impressive demonstration of acquisition of problem-solving ability in amnesics has been provided by Cohen et al (1985; see also Cohen 1984; Squire & Cohen 1984), using the Tower of Hanoi puzzle. This puzzle is complex (requiring solution of a series of nested subproblems), and practice effects are predicated on the recursive nature of the problem being reflected in subjects' solution strategies. A heterogeneous group of amnesics showed completely preserved practice effects (measured in terms of reduction in number of moves to solution) over 16 attempts to solve the problem (4 per day for 4 days). A direct memory test was constructed by presenting the puzzle in intermediate stages of solution. Some of these configurations were on the optimal 31-move solution path and would have been encountered previously; others were not on the optimal path and would not have been encountered previously. On this recognition test, amnesics' discrimination performance was close to chance, whereas control subjects performed at levels well above chance. As in studies of reading transformed text, practice effects on the Tower of Hanoi puzzle are apparently very persistent: Patient H. M. demonstrated large savings over initial performance levels one year after last solving the puzzle (Cohen 1984). Curiously, Butters et al (1985) failed to replicate normal learning of the Tower of Hanoi puzzle in diencephalic (e.g. Korsakoff syndrome) amnesics; they attribute this failure to a impairment in "initiating and ordering of problem-solving strategies," so that "failure to acquire the . . . solution does not necessarily indicate an impairment in procedural learning" (pp. 741-742).

EVALUATIVE RESPONSE Following up on anecdotal evidence of Claparède (1911/1951), Johnson et al (1985) studied acquisition of affective reactions in Korsakoff patients. In one experiment, Korsakoffs were found to rate melodies that they had heard before in the experiment as more pleasant than new melodies; this affective bias was the same in Korsakoffs and controls, where-as recognition of old melodies was significantly impaired in Korsakoffs compared to controls.

In another experiment, subjects were given biographical information about two males depicted in photographs; one stimulus person was described in positive terms, the other in negative ones. Later they were asked to indicate preference for one or the other of the two men. In this situation, amnesics did not show as extreme a bias in favor of the positively characterized stimulus person as did controls. Johnson et al attributed this failure to find equivalence in the preference test (an indirect test) to the control subjects' conscious use of specific biographical information to determine affective response; by contrast, information of this type was not available to control subjects in the case of melodies, limiting the influence of reflective retrieval processes on the affective ratings.

### Temporary Change in Brain State

Effects of drugs and hypnosis have been cited as dissociating direct and indirect tests (e.g. Hashtroudi et al 1984; Kihlstrom 1980; Parker et al 1983; Williamsen et al 1965); however the validity and replicability of these studies have been questioned [McKoon et al (1986); but see also Nissen et al (1987) for more recent drug work, and Kihlstrom (1985) for more recent hypnosis work]. We refer instead to another striking demonstration of this type of dissociation by Squire et al (1985). They administered study-test trials at different times in the recovery period following individual treatments in a course of bilateral ECT, using word completion priming and three-choice recognition memory as dependent measures. Priming recovered at a much faster rate than did recognition memory performance: At 45 min following ECT, priming was normal in comparison to non-ECT controls, whereas recognition memory was at chance. Recognition memory took 9 hr to return to a level approaching that shown by controls.

## Normal Subjects

LEVEL AND ELABORATION OF PROCESSING, DIFFICULTY OF PROCESSING, There are now numerous demonstrations that AND STUDY-TIME EFFECTS traditional encoding manipulations, while producing strong effects on performance in a direct test, do not affect the extent of repetition effects in an indirect test. In Jacoby & Dallas (1981), manipulating the level of processing (LOP) of study words did not change the size of the repetition priming effect in perceptual identification, but it produced large effects on recognition memory (semantically processed words yielding better performance than phonemically or orthographically processed words). In subsequent studies, null effects of study LOP on repetition priming have been found for word completion (Graf & Mandler 1984; Graf et al 1982), lexical decision (Kirsner et al 1983, Expts. 2 & 3; Monsell 1985), picture naming latency (Carroll et al 1985, Expts. 1-3), and perceptual identification of pictures (Carroll et al 1985, Expt. 4). Further, Begg et al (1985) found that LOP at study did not influence the advantage of repeated over nonrepeated statements in ratings of

credibility. In each of the studies cited, a direct memory test (across studies, free recall, cued recall, and recognition) showed a large effect of LOP for the same items. An exception to this general trend is Squire et al (1987, data from control subjects), in which an LOP effect on fragment completion priming was found; the authors attribute this finding to the spontaneous use of explicit memory for deeply processed items in the indirect test.

Increasing elaborative processing at study enhances direct memory performance (e.g. Bradshaw & Anderson 1982) but does not appear to influence repetition priming. Richardson & Bjork (1982) had subjects rehearse auditorily presented words imaginally in a prefamiliarized speaker's voice; rehearsal was either rote or elaborative. Priming was equivalent for the two types of rehearsal in a subsequent auditory perceptual identification test; however, elaborative rehearsal produced better recognition memory than did rote rehearsal. Consistent with this result, Graf & Schacter (1985) and Schacter & Graf (1986a) showed that elaborative processing (e.g. generating a sentence including the study word) did not increase the amount of direct priming obtained in word completion, in comparison with a condition in which study words were orthographically processed. Similar results were obtained in free-association priming with common idioms and highly related word pairs as study materials (Schacter & Whitfield 1986). Finally, Greene (1986) found no effect on word completion priming of intention to learn at study (presumed to influence elaborative activity). In the latter four studies large effects of amount of elaboration on cued recall were observed.

Jacoby & Dallas (1981) investigated effects of difficulty of encoding and study time. They showed that reading a word resulted in as much priming of later perceptual identification as did producing that word as a solution to an anagram; by contrast, solving anagrams produced much better recognition memory for studied items than did reading. Similarly, increasing study time (by slowing rate of presentation of study words) enhanced recognition memory but did not affect the magnitude of priming. Consistent with the latter result, Richardson and Bjork (1982) found no effect of duration of rehearsal in an imagined voice on priming of auditory perceptual identification (for both rote and elaborative types of rehearsal), and Greene (1986) obtained a null effect of rehearsal duration on word completion priming. Increasing rehearsal duration in these studies resulted in significant improvements in recognition and in cued recall, respectively.

DEVELOPMENTAL DISSOCIATIONS Schacter & Moscovitch (1984; Schacter 1984; Moscovitch 1985) reinterpreted the data on the early development of memory as showing that there are "early" and "late" memory systems, the latter beginning to emerge only 8–9 months after birth. Before the emergence of the late system, "behavior may be modified but without any recollection of

a previous episode" (Moscovitch 1985, p. 80). They regard data on infant search errors as reflecting memory deficits associated with inability to recollect episodes (for a similar view, see Bjork & Cummings 1984). Performance on indirect memory tests (habituation, novelty preference, certain types of conditioning tasks) would not be expected to show a developmental trend from 8–12 months; performance on direct tests (object search, other types of conditioning) would show such a trend as the late system developed. Here again a variable is associated with performance on direct tests, but not with performance on indirect tests.

Schacter & Moscovitch (1984) argued that the late system is impaired in amnesia. To support this argument, they showed that memory-disordered patients (including early Alzheimer's patients and amnesics) perform poorly on the type of object search task originally used by Piaget in his investigations of object permanence. The poor performance of memory-disordered subjects was due to intrusions of responses made in prior trials in which the object was hidden at a different location than the current one (a phenomenon they term *mnemonic precedence*); however, such intrusions could not be attributed to perseveration associated with frontal lobe pathology (e.g. Moscovitch 1982) because patients with frontal lobe damage performed well at the task.

### Stochastic Independence

A supplementary strategy to generating functional dissociations has been to test for stochastic independence between direct and indirect tests. The principal demonstrations of independence/nonindependence are summarized first. That summary is followed by a discussion of the effects that can contaminate such analyses—effects that themselves must be accounted for before theoretical implications can be attributed to independence or dependence across measures.

OBSERVED INDEPENDENCE AND DEPENDENCE In the face of objections to his use of functional dissociations of the type described above to support the episodic-semantic distinction (e.g. Hintzman 1984; Roediger 1984), Tulving (1985a) has emphasized the importance of stochastic independence between different measures of memory, arguing that this type of independence places tighter constraints on theory. He points out that functional independence or dissociation can be explained by assuming that one or more processing stages is common to different tasks, but that others are used for one task but not for the other (as in generation-recognition models of recognition and recall—e.g. Anderson & Bower 1972). On the other hand, "as long as there is any overlap in those operating components that are responsible for differences in what is retrieved, some positive dependence between measures should appear. Per-

fect stochastic independence implies complete absence of such overlap" (1985a, p. 395).

The classic examples of stochastic independence are studies by Jacoby & Witherspoon (1982) and Tulving et al (1982). In the former study, the probability of recognizing a primed homophone as having been studied was no greater when calculated as a proportion of those words spelled in the biased fashion than when calculated without regard to spelling status. This result held for both normals and Korsakoff amnesics, even though their overall rates of correct recognition differed by about 50%. Jacoby & Witherspoon obtained similar results from the perceptual identification-recognition paradigm, using word stimuli: The probability of perceptual identification given recognition was equivalent to the simple probability of perceptual identification. Tulving et al (1982) found that probability of recognition conditionalized on successful fragment completion was equivalent to the overall rot orditionalized in overall recognized, for four conditions that differed in overall recognition of words recognized, for four conditions that differed in overall recognition probability.

Tulving (1985a) presents further more recent examples from his laboratory of stochastic independence between recognition and indirect memory tasks. In Chandler's (1983) master's thesis, fragment completion and recognition were studied under 32 different conditions, including conditions in which the relation between the word fragments and the study list words was pointed out to subjects at test. Other indirect memory tasks used by Tulving's students were anagram solution and identifying the presence of a face in an ambiguous drawing. Probability of recognition conditionalized on fragment completion, anagram solution, or face identification was essentially equivalent to the simple recognition probability across 39 conditions. These conditions varied in simple probability of recognition between .03 and .88 (approximate values). Additional examples of stochastic independence are given by Eich (1984) and Light et al (1986).

A number of exceptions to stochastic independence have been observed. For example, dependence was found when nonword stimuli were used in perceptual identification (Jacoby & Witherspoon 1982), when subjects were instructed to use word fragments to help retrieve study-list words (G. Hayman, unpublished observations cited in Schacter 1985b), and when a completion test preceded a recognition test (Light et al 1986; Shimamura & Squire 1984; Tulving et al 1982). The first two examples might be explained by assuming that subjects used explicit memory in both the direct and indirect tests (e.g. Schacter 1985b). The latter example brings up the important issue of intertest biases, which we consider next.

CONTAMINATING EFFECTS Some critics have argued that stochastic independence (and sometimes dependence) is often an artifact produced by the influence of the first test on the second test (e.g. Mandler et al 1986; Shimamura 1985). This problem is fundamental and formidable. The stochastic-independence logic requires that a given subject be tested on the same item in more than one way. It is simply an implausible assumption that the item exposures and subject reactions that comprise a first test leave the memory system unaltered and ready to give an uncontaminated picture of the influence of the study episode on a second test of some type. Shimamura (1985) presents examples illustrating that independence can appear when dependence is in fact the case, and vice versa, depending on the nature of the two tests and the presumed influence of the first test on the second test. When a completion test occurs before a recognition test, stochastic dependence is likely to result because the completion test represents an additional study trial for items successfully completed (Tulving et al 1982). This dependence could occur even when the information tapped by the two tests was in fact uncorrelated. More important, when a recognition test precedes a completion test, and the recognition test boosts later completion performance, the interest bias is towards independence, even when dependence between measures exists in fact.

At a more advanced stage of theory development, tests of stochastic independence may prove to be more important and useful. When our theories of memory as revealed in direct and indirect tests are complete enough, and quantitative enough, to account for the effects of one test on another, such effects can potentially be partialled out of tests for stochastic independence [e.g. Flexser & Tulving (1982) attempt to model the priming of subsequent recall attributable to an item's exposure on a prior recognition test]. Even now, there are cases in which we can specify with some confidence whether the effect of one test on another should work towards producing independence or dependence. Given that the observed outcome is in the opposite direction, we may be relatively safe in attaching theoretical significance to the result.

Although some current examples of independence and dependence may be statistically interpretable, difficulties remain in drawing theoretical implications from such results. Tulving's critics do not agree that stochastic independence between direct and indirect measures represents convincing evidence for multiple memory systems, or even for absence of process overlap between tests, arguing instead that independence could result from absence of overlap in the information provided by different test cues (e.g. Flexser & Tulving 1978; Shoben & Ross 1986). It is not possible to discriminate between the opposing interpretations because none of the currently viable theories is precisely specified enough to permit deduction of dependence or independence between direct and indirect measures from its premises. A consequence of this problem is that findings of stochastic independence and dependence play little role in discriminating between competing theories of the relationship between direct and indirect measures.

### PARALLEL EFFECTS ACROSS MEASURES

### Repetition Effects

Using a study-test procedure, Jacoby & Dallas (1981, Expts. 4a,4b) found that presenting items twice at study resulted in greater priming of perceptual identification than did presenting them once (if the presentations of twice-presented items were spaced); this repetition effect mirrored that found in recognition memory. (Of course, the positive effects of repetition in direct memory tests are well known; see Crowder 1976, Ch. 9). Feustel et al (1983) extended this result using a continuous identification procedure and somewhat different measures of perceptual identification performance: Across a number of experiments perceptual identification performance was enhanced monotonically as a function of the number of presentations of an item (1, 2, or 3). Effects of repetition on word completion and recognition have also been found to be parallel (Graf & Mandler 1984).

Feustel et al (1983) confirmed the similarity between the effects of repetition on recognition and perceptual identification by presenting words that were different in meaning from previously repeated words, but highly similar in orthography (e.g. *huge* presented following prior repetition of *hug*). Identification of these *derived words* was improved by prior presentation of the words from which they were derived (an indirect priming effect); additionally, subjects made more false positive responses to the derived words than to underived new words in a recognition memory test.

### Level of Attention at Encoding

Experiments reviewed above suggested that manipulations of orienting task at encoding did not affect the strength of repetition priming, but strongly influenced performance on direct tests. The insensitivity of repetition priming to the nature of encoding processes seemed to be confirmed by demonstrations of effects of prior exposure in the absence of attentional encoding. In studies by Zajonc and colleagues (e.g. Kunst-Wilson & Zajonc 1980; Wilson 1979; Zajonc 1980) stimuli were presented for initial study under conditions that led to chance recognition memory performance in a later test (e.g. visual presentation at extremely brief durations, or auditory presentation on an unattended channel in dichotic listening). Despite their inability to recognize "old" stimuli, subjects displayed affective preference for those stimuli over "new" stimuli. Similar results were obtained using visual presentation by Seamon et al (1983a,b, 1984; but see also Mandler & Shebo 1983). Eich (1984) combined the dichotic listening technique with Jacoby & Witherspoon's (1982) homophone spelling paradigm; biasing primes were presented over the unattended channel in the study phase. At test, subjects showed a spelling bias for primed homophones in conjunction with chance recognition for "old" items. In sum, when conscious or attentional processing in the initial exposure phase is difficult or impossible, the behavior of normals seems to mimic that of amnesics under attentional encoding conditions (e.g. Jacoby & Witherspoon 1982; Johnson et al 1985).

Although studies of this type permit the conclusion that attentional encoding is not necessary for prior-exposure effects to occur, they typically do not include a control condition in which stimuli are attentionally encoded at study. This omission prevents the conclusion that the indirect measure in question is insensitive to a manipulation of level of attention to which a direct measure is sensitive. In short, studies that do not manipulate level of attention at study cannot be said to have demonstrated dissociations between direct and indirect measures analogous to those found in comparisons of amnesics and normals, or in manipulations of orienting task at encoding.

Studies of affective preference that include appropriate manipulations have yielded mixed results. Seamon et al (1983a) compared a condition in which subjects shadowed an auditory message during initial brief visual presentations to a condition in which no shadowing was performed. In one experiment, affective preference was greater for attended than for unattended stimuli, and a similar advantage for attended stimuli was found in recognition memory. Results from two other experiments were less clear-cut, but in no case did the shadowing variable interact with the type of test (preference vs recognition), as would be expected if level of attention dissociated the two tests. A different pattern was obtained by Seamon et al (1984), who manipulated stimulus exposure duration in the study phase. At test, the effect of prior exposure on affective judgments was little influenced by exposure duration (from 2 msec through 48 msec); by contrast, items exposed for 24 msec at study were recognized much better than those exposed for 8 msec.

By contrast, studies in the lexical domain give much stronger evidence for the role of attention in priming effects. Eich (1984) presented biasing homophones over an unattended or an attended channel. As expected, recognition memory performance was much better for attended than for unattended study items; however, attended primes also biased later spelling to a greater extent than did unattended primes. Jacoby & Brooks (1984) had subjects search for members of a target semantic category in a series of words presented rapidly (300 msec/item) in one position on a CRT screen. Half of the items in the series were target-category exemplars; the remainder were members of the same nontarget category. In a later perceptual identification test, old members of the target category were identified better than new members of the same category. The difference between old and new items for nontarget-category items was much smaller than that for target-category items. This study is flawed because target items (but not nontarget items) were recalled following the study phase (perhaps accounting for their superior

identifiability), and because no comparison of direct memory for targets and nontargets was made to permit assessment of differential versus parallel effects across a direct and an indirect test. However, the results are suggestive of an effect on perceptual identification that parallels the effect of comparable manipulations in direct memory studies (e.g. Fisk & Schneider 1984).

Similar results have been obtained in lexical decision studies. In a study by Oliphant (1983), repeated words received their first presentation either as part of the typewritten instructions for the lexical decision task, or as stimuli in the lexical decision task. Only the latter condition resulted in repetition priming; reading words as part of the instructions conferred no benefit on later lexical decisions concerning those words. This result can be given an attentional interpretation: Individual items receive less attentional processing when they are presented as part of a coherent body of text than when they are presented as individual items in the lexical decision task. This reasoning is confirmed by the results of Monsell & Banich (in Monsell 1985), who found weaker repetition priming in lexical decision when primes were read as part of sentences than when they were presented as stimuli in the lexical decision task. Finally, Forster & Davis (1984) found that the frequency-attenuation effect in lexical decision was eliminated when the first presentation of to-berepeated items was masked so that the prime was minimally available to awareness. The frequency-attenuation effect refers to the finding that lowfrequency words benefit more from repetition than do high-frequency words, so that repetition attenuates the usual superiority of high-frequency words (e.g. Jacoby & Dallas 1981; Kirsner et al 1983; Nelson et al 1984; Scarborough et al 1977, 1979). When primes were masked, repetition conferred equal benefits on subsequent processing of low- and high-frequency words; this result suggests that attentional encoding plays an important role in producing the repetition effect for low-frequency words.

### Reinstating List Context

Jacoby (1983a) showed that the magnitude of the repetition priming effect in perceptual identification was positively related to the ratio of the numbers of primed and unprimed words on the test list. The priming effect was larger when primed words constituted 90% of the test list than when they constituted only 10% of the test list. In another experiment, subjects received study-test trials on five consecutive days. Words studied on the fifth day were identified better when they alone constituted the old times on the test list than when they were mixed with old items from previous days. According to Jacoby these results show that repetition priming is sensitive to contextual reinstatement in the same way that direct tests of memory are. Jacoby (1983a; see also Jacoby & Witherspoon 1982) also investigated the influence on priming of match

between environmental contexts at study and test, with generally negative results. However, since null effects of incidental environmental context have been obtained in recognition memory (e.g. Godden & Baddeley 1980; Smith et al 1978) and recall (Bjork & Richardson-Klavehn 1987; Eich 1985; Fernandez & Glenberg 1985), failure to obtain effects on priming measures cannot be taken to imply that indirect measures are less sensitive to environmental context than are direct measures.

### Influence of New Associations

In their critique of the episodic-semantic distinction, McKoon et al (1986; Ratcliff & McKoon 1986) place considerable emphasis on studies comparing indirect priming effects in lexical decision and recognition memory tasks. In the context of task-comparison methods there are two questions of interest: (a) Are lexical decision and recognition influenced similarly or differently by presentation of information that is semantically related to the target word (semantic priming), and (b) are lexical decision and recognition influenced similarly or differently by the presentation of an item that was first associated with the target in the experimental context (episodic priming)? McKoon et al base their arguments on the assumption of similarity of effects across the direct and indirect tasks. However, studies investigating these questions have produced mixed results, with some showing dissociative effects (e.g. Carroll & Kirsner 1982; Neely & Durgunoğlu 1985) and others suggesting parallel effects (e.g. McKoon & Ratcliff 1986; McKoon et al 1985; Ratcliff & McKoon 1981; Ratcliff et al 1985). Durgunoğlu & Neely (1987) have shown that differences in experimental procedures are responsible for the apparent inconsistencies in the results; in particular, episodic priming of lexical decision occurs only when numerous experimental conditions are conjointly satisfied. The procedural complexities of such studies are too great to permit a detailed treatment here.

We refer instead to work of Graf & Schacter (1985, 1987; Schacter 1985a,b; Schacter & Graf 1986a,b), which clearly demonstrates that performance in an indirect test can be influenced by new associations. In the basic experiment, word pairs are presented, the stimulus and response terms of each pair bearing no preexperimental relationship to each other (e.g. *window-REASON*). The subject must generate a meaningful association between the two words. In the word completion test, subjects are given three-letter stems accompanied by a stimulus word that is the same as at study (same-context condition—e.g. *window-REA\_\_\_\_\_\_*), or different, but also normatively unrelated to the response word (different-context condition—e.g. *officer-REA\_\_\_\_\_\_*). Although priming (relative to baseline completion performance) is observed in the different-context condition, preserving the stimulus word from the study list (same-context condition) significantly increases

the probability that the subject will generate a list word. The difference between the same- and different-context conditions represents an episodic priming effect due to the retention of a new association. Moscovitch (1984, 1985; Moscovitch et al 1986) has obtained similar results in studies of reading transformed and degraded script. Increases in reading speed for pairs of words whose members have been read before are greater for test pairs whose members were previously read together as a pair (old pairs) than for test pairs consisting of words that were read as parts of different pairs in the study phase (recombined pairs). Again, the results show the influence on an indirect memory measure of an association formed during prior exposure to the test materials.

As would be expected, direct tests also reveal the influence of new associations. In the experiments of particular interest here (Schacter & Graf 1986a, Expts. 1 & 2), deliberate recall of study-list words using the word stems as cues (*letter-cued recall*, a form of direct test) was influenced in the same way as word completion priming by the contextual manipulation. Same-context responses were recalled significantly more often than were different-context responses. These cued-recall results mirrored previous results in recognition memory: DaPolito et al (1972) showed that words studied in the context words were reinstated at test than when the context words were removed or replaced with different words. In sum, cued recall and recognition were influenced in the same way as was word completion by the formation of new associations.

Graf & Schacter (1985; see also Schacter & Graf 1986b) showed normal episodic priming effects on word completion in amnesic subjects; the same subjects were subsequently severely impaired in a test of cued recall for the response terms of studied pairs (a direct test for associations formed during study). Moscovitch (1984, 1985; Moscovitch et al 1986) also demonstrated normal retention of new verbal associations in memory-disordered patients, even though these patients were severly impaired when asked to discriminate old from recombined pairs of words. These demonstrations of the acquisition of verbal associations complement prior demonstrations of eye-blink (Weiskrantz & Warrington 1979) and galvanic skin response (Rees-Nishio, in Moscovitch 1985) conditioning in memory-disordered patients. The results in memory-disordered patients suggest that retention of new associations as revealed by indirect tests is not due to explicit retrieval of associations; they therefore support McKoon et al's (1986) claim that episodic priming is automatic/unconscious.

## Memory for Facts Versus Memory for Experiences

Anterograde amnesia in memory-disordered patients is not limited to performance on tests whose instructions make explicit reference to a prior episode. Learning of new facts (e.g. Cermak & O'Connor 1983; Schacter et al 1984; Shimamura & Squire 1987) and vocabulary (Gabrieli et al 1983; Glisky et al 1986a) is impaired, although memory-disordered patients are able to acquire and use some new information relating to particular domains when learning and testing techniques are appropriately contrived (e.g. Glisky & Schacter 1987; Glisky et al 1986a,b; Schacter & Glisky 1986; Schacter et al 1985). Memory-disordered patients also exhibit retrograde amnesia, although the severity and temporal extent of retrograde impairment vary considerably across patients with different etiologies (for a summary, see Butters & Cermak 1986). To the extent that retrograde impairment occurs, however, it covers memory for past public events and figures, and for past television shows (e.g. Albert et al 1979; Butters & Albert 1982; Cohen & Squire 1981; Meudell et al 1980; Squire & Cohen 1982).

Tests of factual information, vocabulary, and remote memory for public information meet only some of the criteria for inclusion as indirect tests. Their task instructions do not typically make explicit reference to a prior episode in the history of the individual; on the other hand, the measures involved are not derived from comparison of two or more data points, and an individual is necessarily aware of remembering in some sense when performing some of these tests. Nonetheless, such tests are clearly not direct tests, and the data from such tests therefore represent an exception to the generalization that memory-disordered patients show deficits only in direct tests of memory.

### COMPLEX PATTERNS ACROSS MEASURES

Recent research has shown that patterns of dissociations and parallel effects across direct and indirect measures of memory vary systematically as a function of certain critical variables.

### Conceptually Driven Versus Data-Driven Tests

Performance in indirect tests is often more dependent on match between perceptual conditions at study and test (such as modality of presentation) than is performance in direct tests. Sensitivity to match between study and test context is one of the criteria used to determine whether a test involves retrieval of episodic information. Such dissociations therefore seem paradoxical because indirect measures of memory have traditionally been assumed to reflect modification of an abstract (context-free) representation, whereas direct measures have been assumed to depend on information about spatiotemporal context.

Following up on an argument made by Roediger (1984), Blaxton (1985) and Roediger & Blaxton (1987a) have proposed that the apparent generality of such dissociations is an artifact of a failure to consider a wide enough range of direct and indirect memory tests. Most indirect tests can be classified as

*data-driven* because the subject is required to operate on perceptual information provided by the experimenter (e.g. fragment completion, perceptual identification); the data-driven nature of most indirect tests accounts for their sensitivity to perceptual context. On the other hand, direct tests usually involve a significant amount of *conceptually driven* processing because the subject must mentally reconstruct the study episode (e.g. in free recall). However, the data-driven/conceptually driven and indirect/direct taxonomies are by no means coextensive. Indirect tests can be conceptually driven (e.g. retrieval of facts and general knowledge), and direct tests can be data-driven (e.g. cued recall with extralist cues that are graphemically similar to studied items). Recognition memory tests usually involve a blend of data-driven and conceptually driven processing; the subject operates on perceptual data provided by the experimenter, but must often reconstruct the study episode in order to perform accurately.

In the context of the data-driven/conceptually driven taxonomy the literature on perceptual and linguistic context effects shows a remarkable degree of consistency: Manipulations of similarity between linguistic or perceptual context at study and test affect data-driven tasks similarly, regardless of direct/indirect status; manipulations of elaboration at study affect conceptually driven tasks similarly, regardless of direct/indirect status. Tests of recognition memory align themselves either with data-driven or with conceptually driven tasks, depending on the types of processing permitted by the specific experimenatal circumstances.

The term generation effect (Slamecka & Graf THE GENERATION EFFECT 1978) refers to the advantage-in terms of later recall or recognition performance-of generating rather than reading information in the study phase. In Jacoby's (1983b) study, reading a word produced greater priming of later perceptual identification than did generating that word in response to a related word; by contrast, study words that were read were more poorly recognized than study words that were generated. Blaxton (1985, Expt. 1) replicated this dissociation using free recall and fragment completion as the direct and indirect tests, respectively. Winnick & Daniel (1970, Expt. 2) and Clarke & Morton (1983, Expt. 1) obtained similar dissociations between free recall and visual duration threshold (VDT). Generating a word from a definition led to better free recall than did reading a word; however, reading a word reduced its later VDT significantly, whereas generating the word did not. This crossover interaction occurred despite the fact that type of test was within-subjects in both studies, with free recall preceding the identification test. Completing this general pattern, Monsell & Banich (cited in Monsell 1985) found priming in a visual lexical decision task only when tested words had previously been read, but not when they had been generated from a definition or as a completion to a

proverb; in auditory lexical decision the generation condition resulted in significant priming, but priming in this condition was attenuated compared to the read condition. On indirect tests in these studies, amount of priming was positively related to similarity of the perceptual form of a word at study and test. In contrast, a generation advantage occurred for a visual test of recognition memory, even though generating a word at study meant that the word was not visually presented until test (Jacoby 1983b).

In support of the data-driven/conceptually driven taxonomy of tests described above, Blaxton (1985; see also Roediger & Blaxton 1987a) has shown that the generation effect dissociates some pairs of direct and indirect tests but produces parallel effects on other pairs. In her experiment, subjects either generated a study word from a cue (e.g. tin-C\_\_\_\_) or read the word in the absence of a meaningful context (e.g. XXX-COPPER). Two direct memory tests were used: free recall, and cued recall with extralist cues that were graphemically similar to to-be-remembered items (e.g. CHOPPER was a cue for *COPPER*). The two indirect tests were fragment completion and a general knowledge test (e.g. "What metal makes up 10% of yellow gold?"). Generating the study word produced better performance than did reading it for the free recall test and for priming in the general knowledge test; by contrast, reading the study word was superior to generating it for the graphemically cued recall test and for fragment completion priming. In sum, dissociations between direct and indirect tests were observed in comparisons of free recall with fragment completion (replicating the dissociations reported by Jacoby 1983b and others), and graphemic cued recall with general knowledge retrieval; however, parallel effects were observed in comparisons of free recall with general knowledge retrieval and graphemic cued recall with fragment completion. With respect to the direction of the generation effect, then, the tests group themselves according to the data-driven/conceptually driven taxonomy, and not according to the direct/indirect taxonomy.

PICTURE-WORD EFFECTS Studies that have manipulated whether an item is presented for study in its pictorial or its verbal form have yielded patterns of results very similar to those in studies of the generation effect. A large literature demonstrates the superiority of pictorial over verbal presentation in free recall, cued recall, and recognition memory tests (for a summary, see Roediger & Weldon 1987). By contrast, priming in indirect tests is often greater when items are presented for study as words than when they are presented as pictures. Winnick & Daniel (1970, Expt. 2) found the standard picture superiority effect in free recall; however, VDTs were lower for items studied in verbal form than for those studied as pictures. This crossover interaction between test type and mode of presentation occurred despite the fact that the free recall test was administered to subjects before the VDT test.

The picture-word variable produces similar dissociations between recognition memory and lexical decision (Scarborough et al 1979), cued recall (with semantically related extralist associates) and fragment completion (Roediger & Weldon 1987, Expt. 3), and free recall and fragment completion (Weldon & Roediger 1987, Expt. 1). Additionally, naming and semantic categorization latencies for words are reduced more when primes are presented as words than when they are presented as pictures (Durso & Johnson 1979; Durso & Sullivan 1983; Kroll & Potter 1984).

As with the generation effect, performance in recognition is better when physical cues at study and test are different (picture at study, word at test) than when they are the same (word at study, word at test); by contrast, the indirect tests that have been studied are highly sensitive to match/mismatch between the physical cues at study and test. However, picture superiority is not an intrinsic property of direct memory tests. Roediger & Weldon (1987, Expt. 2) showed that the picture superiority effect was eliminated in a direct test when subjects were given fragments of studied items and told to use them to retrieve studied words (a data-driven test). Similarly, word superiority is not intrinsic to indirect tests. When the indirect test consists of naming a picture (Durso & Johnson 1979), categorizing a picture (Durso & Johnson 1979; Kroll & Potter 1984), identifying a tachistoscopically presented picture (Warren & Morton 1982), or identifying a fragmented picture (Weldon & Roediger 1987, Expt. 4), picture primes produce more facilitation than do word primes.

Roediger & Weldon (1987) suggest that picture-word effects can best be conceptualized in terms of the interaction of study conditions and test demands. Additional support for their position comes from a study by Blaxton (1985, Expt. 3). She had subjects form mental images corresponding to certain study words; for other study words subjects simply read the word silently. Consistent with the results on depth and elaboration of processing described above, performance was better under imagery conditions than under no-imagery conditions for free and cued recall tests, but the imagery manipulation did not affect fragment completion priming. However, imagery at study also improved priming on a general knowledge test (an indirect conceptually driven test) but did not affect performance on a graphemically cued recall test (a direct data-driven test). With respect to imagery effects, therefore, memory tests honor the data-driven/conceptually driven distinction, and not the direct/ indirect distinction.

EFFECTS OF LANGUAGE Kirsner & Dunn (1985) review six studies of repetition priming in bilingual subjects (across studies subjects spoke English as one language and in addition either French, Hindi, Italian, Spanish, or Turkish). Language of items at study and test was manipulated such that a concept presented in a particular language at study was tested either in the same or in a different language. Tests used were fragment completion (Watkins & Peynircioğlu 1983), lexical decision (Cristoffanini et al 1986; Kirsner et al 1984; Scarborough et al 1984), and semantic classification (R. Harvey, unpublished observations). Conditions in which words in the different languages were cognates (e.g. publicidad vs publicity) or in which they differed only in script but not in phonology or reference (as in certain words used in both Hindi and Urdu, Brown et al 1984) were excluded. To permit comparison of data from different tests and conditions, Kirsner & Dunn computed a relative priming ratio by dividing the amount of priming (performance on old items minus performance on new items) obtained in the different-language condition by the amount of priming obtained in the same-language condition. Averaged over nine conditions the relative priming ratio was  $.05 \pm .09$  SD, indicating essentially no cross-language priming. Kolers (1975) has obtained similar effects. Studying a sentence in normally oriented French primed later reading of the same sentence in geometrically inverted English less than did reading that sentence in normally oriented or inverted English. At longer lags between initial study and test, reading a sentence in French resulted in no transfer at all.

The test used by Watkins & Peynircioğlu (1983) was treated by Kirsner & Dunn (1985) as fragment completion; however, by the classification criteria given above, it should be considered a graphemically cued recall test (a direct data-driven test), because subjects were told to use word fragments to help recall study words. Surprisingly, language context effects with graphemic fragment cues do not seem to depend on whether or not the test instructions refer to the study episode: Durgunoğlu & Roediger (1987; see also Roediger & Blaxton 1987a) also failed to obtain cross-language priming in an indirect fragment completion test. The important implication of these two studies taken together is that linguistic context effects are observed in data-driven tests, regardless of whether such tests are direct (Watkins & Peynircioğlu 1983) or indirect (Durgunoğlu & Roediger 1987).

Durgunoğlu & Roediger (1987) also included the critical intraexperiment comparison between the effects of language (Spanish vs English) on direct and indirect tests. In the conditions of interest, study words were presented twice, either in the same language on each presentation (e.g. *caballo, caballo; horse, horse*), or in a different language (e.g. *caballo, horse*). Presenting a word in Spanish produced no significant priming for a fragment completion test given in English; however, presenting it in English or in mixed languages did produce significant priming. These results are completely consistent with those of the studies reviewed by Kirsner & Dunn (1985). In a free recall test, the mixed language condition produced better recall than the pure language conditions, but there was no difference between the English-English and Spanish-Spanish conditions. In a recognition memory test conducted in En-

glish, words studied in Spanish were recognized well above chance, but not as well as words studied in English, and mixed language words were recognized best. The superiority of mixed language words in recall and recognition can be attributed to the positive effects of encoding variability (e.g. Melton 1970). The absence of an effect of language on free recall is difficult to interpret, since subjects were allowed to recall words in Spanish or English, so test language was not controlled as in the other two tests.

In sum, a change in language context attenuates priming in indirect tests (fragment completion, lexical decision, semantic classification) and produces performance decrements in some direct tests (recognition, recall with graphemic cues). These direct and indirect tests share data-driven components. The effect of language context on conceptually driven tests, such as free recall and general knowledge retrieval, remains to be established in conditions in which language of input and output is systematically manipulated.

MODALITY EFFECTS A considerable number of studies have shown that priming in indirect tests is attenuated by a change in modality of presentation between study and test. For both auditory and visual tests, the manipulation of interest is whether items are studied in the visual or the auditory modality. In all 24 experiments from the 14 studies we reviewed, priming was significantly reduced when input and test modalities mismatched (i.e. visual priming for auditory test, or auditory priming for visual test), compared to the case in which input and test modalities matched.

Modality effects have been demonstrated in visual tests of fragment completion (Blaxton 1985, Expt. 2; Roediger & Blaxton 1987b, Expts. 1 & 2), lexical decision (Kirsner et al 1983, Expts. 2 & 3; Kirsner & Smith 1974; Monsell & Banich, in Monsell 1985), perceptual identification (Clarke & Morton 1983, Expts. 2 & 3; Jacoby & Dallas 1981; Jacoby & Witherspoon 1982: Kirsner et al 1983, Expts. 1, 4–8; Postman & Rosenzweig 1956), and word completion (Graf et al 1985). Additionally, Kolers (1975) reports that speed of reading a geometrically inverted sentence is not facilitated as much by prior auditory presentation of that sentence as it is by prior reading of that sentence in either normal or inverted form. Similarly, Levy (1983) found that exposure to a passage facilitated later detection of typographical errors in that passage in a proofreading task, but that this facilitatation effect was smaller when initial exposure to the passage was auditory than when it was visual. Auditory tests of lexical decision (Kirsner & Smith 1974; Monsell & Banich, in Monsell 1985) and perceptual identification (Ellis 1982; Jackson & Morton 1984; Postman & Rosenzweig 1956) also show modality effects, with auditory presentation of study words producing greater priming than visual presentation.

In most of the experiments we reviewed, performance in the differentmodality condition, though attenuated in comparison to the same-modality condition, was still better than performance on new items; however, a few studies have failed to obtain such cross-modality priming. Clarke & Morton (1983, Expt. 2), Jacoby & Dallas (1981), and Postman & Rosenzweig (1956) found no significant effect of auditory study on later visual perceptual identification; Monsell & Banich (in Monsell 1985) obtained a similar null effect in a visual lexical decision test. Ellis (1982) found no transfer from visual study to auditory perceptual identification, and Kirsner & Smith (1974) found very little transfer from visual study to auditory lexical decision. In all these cases there are counterexamples in which significant cross-modality priming was obtained using the same type of test (visual perceptual identification: Clarke & Morton 1983, Expt. 3; Kirsner et al 1983; visual lexical decision; Kirsner et al 1983; auditory perceptual identification: Jackson & Morton 1984; auditory lexical decision: Monsell & Banich, in Monsell 1985). The reason for this discrepancy between studies is currently unclear.

Kirsner & Dunn (1985) reviewed the results of six of the studies of modality effects in lexical decision and perceptual identification discussed above. Across 16 conditions from the six studies, mean relative priming (the ratio of priming in the different-modality condition to priming in the same-modality condition) was  $.38 \pm .24$  SD, indicating that priming effects were attenuated considerably by a change in modality, but not eliminated. The results of their survey are therefore consistent with those of ours, which includes a larger range of indirect tests.

Only a few studies have directly compared modality effects in direct and indirect tests; these studies indicate that modality is generally a less important factor in direct than in indirect tests. Graf et al (1985) obtained no difference between visual and auditory presentation for a free recall test, in conjunction with a significant effect of modality on word completion; Blaxton (1985) obtained the same pattern of results across tests using free recall and fragment completion. Advantages of auditory over visual presentation in recall seem to occur only at relatively short retention intervals and with particular experimental procedures, although it is now clear that they persist over longer durations than once thought (e.g. Conway & Gathercole 1987; Greene 1985).

Results have been more mixed with respect to recognition memory than with respect to free recall: Kirsner et al (1983, Expts. 1–3) found no effect on recognition memory of modality match versus mismatch between study and test, in conjunction with a significant modality effect on lexical decision; this pattern of results was duplicated by Roediger & Blaxton (1987a) using recognition and fragment completion tests. Modality effects have sometimes been observed in recognition memory, but they vary in size (e.g. compare Jacoby & Dallas 1981 to Kirsner 1974). The variable results with recognition

memory can be understood under the assumption that different study and test conditions lead to variations in the amount of conceptually driven processing possible at test. Effects of modality would be observed in cases in which subjects could not make use of elaborative processes at study or test, or both. In the Jacoby & Dallas (1981) work, items were presented for study at a 1-sec rate, probably accounting for the large effect of modality observed.

As with effects of other forms of context reviewed here, tests group themselves according to the data-driven/conceptually driven distinction where modality effects are concerned. Priming of general knowledge retrieval is not modality dependent (Blaxton 1985, Expt. 2), whereas both intralist (Nelson & McEvoy 1979a) and extralist (Blaxton 1985, Expt. 2) graphemically cued recall are modality dependent.

EFFECTS OF CASE, SCRIPT, TYPEFONT, TYPOGRAPHY, AND VOICE A number of studies have investigated effects on indirect test performance of match versus mismatch of rather subtle aspects of perceptual context. As in studies of modality effects, the comparison of interest is between a condition in which the perceptual form of an item (case, script, typefont, typography, or voice) is the same at study and test, and a condition in which it is changed between study and test. Our review indicates that effects of reinstating these types of context, though generally small and rarely significant at the level of the individual experiment, are consistent across studies using different tests and different types of contextual manipulation. We therefore simply indicate whether the difference between same- and different-context conditions was in the direction expected under the hypothesis of a context effect. To the degree that such effects exist, however small, they are important theoretically, as we indicate in the final section of this review.

Changing letter case (upper to lower, lower to upper) between study and test has been associated with small reductions of priming in perceptual identification (Feustel et al 1983, Expts. 1 & 3; Jacoby & Hayman 1987; Jacoby & Witherspoon 1982) and in lexical decision for words (Scarborough et al 1977, Expts. 1 & 2), compared with conditions in which case was preserved between study and test. Masson (1986, Expt. 3) studied reading of geometrically transformed script using words presented in mixed case (e.g. *KeTtLe*). The positive effect of prior exposure on reading time was significantly greater when the mixed-case form of a word matched between study and test (e.g. *KeTtLe* at both study and test) than when it mismatched (e.g. study *KeTtLe*, test *kEtTlE*). (For related results in a visual search task, see Brooks 1977.)

Changing script (handwritten to typewritten, typewritten to handwritten) resulted in small decrements in priming in fragment completion (Roediger & Blaxton 1987b, Expts. 1 & 2) and perceptual identification (Clarke & Morton 1983, Expt. 1). Brown et al (1984) used a particularly extreme manipulation

of script in their lexical decision study. They used words that have the same phonology and reference in Hindi and Urdu but are written very differently in the two languages. For subjects bilingual in Hindi and Urdu, the repetition priming effect was about 20 msec larger when scripts matched than when they mismatched.

Levy (1983) found improvements in error detection in a proofreading task as a result of prior experience with the test passage; however, this improvement due to repetition occurred only when the typefont of the passage (IBM Script or Prestige-Elite) was the same on first and second presentations. Kolers et al (1980) showed that the positive effects of naming geometrically inverted letters on later reading of geometrically inverted text are specific to the typefont used for practice and test; however, it should be noted that the study materials were generated from different text pages than were the test materials, so the possible influence of typefont on item-specific effects (i.e. direct priming effects) in this type of reading task remains to be discovered.

Kolers (1975) had subjects read geometrically inverted sentences at test. Some of these had previously been read in normal form; others had been read in inverted form. Both forms of prior experience increased reading speed at test, but reading sentences in inverted form resulted in a larger increase than did reading sentences in normal form. Based on these data, Kolers argues that information concerning the perceptual characteristics of specific items mediates the effects of repetition in reading. Horton (1985) has questioned this claim, arguing that the advantage for sentences first read in inverted form occurred because such sentences received more extensive semantic processing at study than did sentences first read in normal form. To equate semantic processing at study, Horton had subjects read study sentences in two different geometric transformations; sentences were later tested either in the same or in a different transformation. In contrast to Kolers's findings, the positive effects of repetition were largely independent of the similarity between study and test transformations; however, repetition effects in different-typography conditions were consistently slightly (nonsignificantly) smaller than those in same-typography conditions across three experiments. Horton's findings therefore fall into the general pattern of small effects noted here.

Jackson & Morton (1984) used an auditory perceptual identification test in which words were spoken by a female voice. Study words were presented to one group of subjects in that female voice, and to another in a male voice. After statistical correction for performance differences between groups, there was a small advantage for items studied in the same voice as the test voice. However, a condition in which half the study items were presented in the female voice and the remaining half were presented in the male voice produced no decrement relative to the same-voice condition.

Evidence concerning the effects of these types of perceptual context on tests of recognition memory yields a similar pattern. Kirsner (1973) found a

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small but significant advantage of preserving letter case between study and test, and Roediger & Blaxton (1987a) found a small nonsignificant advantage for compatibility between study and test script (handwritten vs typewritten). Sentence recognition experiments have revealed significant effects of compatibility between study and test typography (e.g. Kolers & Ostry 1974; Masson & Sala 1978; Masson 1984). Effects on auditory recognition of compatibility between speaker's voice (male vs female) at study and test have been relatively easy to obtain (e.g. Craik & Kirsner 1974; Geiselman & Glenny 1977). As would be expected of recognition, effects of speaker's voice are obtained only when semantic-elaborative processing is suppressed at study, minimizing the role of conceptually driven processing at test (Geiselman & Bjork 1980).

Consistent with the trends presented above, sensitivity to factors such as letter case and typefont is better predicted by the data-driven/conceptually driven distinction than by the direct/indirect distinction. Blaxton (1985, Expt. 3) found no effect of typefont (uppercase italic vs lowercase elite) on priming in general knowledge retrieval; however, she found small effects of typefont on word fragment completion priming and graphemically cued recall.

NONSEMANTIC SET-SIZE AND DATA-DRIVEN TESTS The similarity in retrieval processing between direct and indirect data-driven tasks is confirmed by D. L. Nelson and coworkers (e.g. Nelson 1981; Nelson & McEvoy 1979a,b; Nelson & McEvoy 1984; Nelson et al 1984). In their experiments, subjects are presented with word endings (e.g.\_\_\_\_ESS, \_ \_\_\_USK) and asked to write the first word that comes to mind that rhymes with each ending. The *nonsemantic set size* of the ending is defined as the number of different rhyming words generated to a given ending (e.g.\_\_\_\_ESS rhymes with 20 items, whereas \_\_\_\_\_USK rhymes with only 5). In cued recall tests with endings as cues (a form of graphemically cued recall), endings that define smaller nonsemantic sets produce better recall than those that define larger sets (Nelson & McEvoy 1979b; Nelson & McEvoy 1984); similarly, in a perceptual identification test, words that come from smaller nonsemantic sets are easier to identify than those that come from larger nonsemantic sets (Nelson et al 1984). As noted above, intralist graphemically cued recall also parallels perceptual identification and other data-driven tests in the way it responds to changes in modality between study and test (Nelson & McEvoy 1979a).

### Relationships Between Implicit Associative Memory, Explicit Associative Memory, and Repetition Priming

As reviewed above, one type of indirect test for a newly formed association requires the subject to complete a stem corresponding to the response word of a studied pair of words when the stimulus member of the studied pair is either present or absent. Superior word-completion priming when the stimulus term of the pair is present (same-context condition), compared to when it is not (different-context condition), indirectly reveals the formation of a new association. (For example, if *window-REASON* was studied, priming is greater when *window-REA\_\_\_\_\_\_* is presented at test, than when officer-*REA\_\_\_\_\_\_* is presented.) Word completion performance in the differentcontext condition (e.g. officer-REA\_\_\_\_\_\_) yields a measure of repetition priming (i.e. priming resulting simply from prior presentation of the response term).

Comparisons of amnesic and normal subjects (Graf & Schacter 1985; Schacter 1985b; Schacter & Graf 1986b), manipulations of the way word pairs are encoded at study (Graf & Schacter 1985; Schacter & Graf 1986a), and interference manipulations (e.g. Graf & Schacter 1987) have demonstrated a complex pattern of similarities and differences between repetition priming, indirect memory for new associations, and direct memory for new associations.

#### IMPLICIT VERSUS EXPLICIT ASSOCIATIVE MEMORY

*Evidence from amnesic subjects* Preliminary evidence from a small number of amnesic subjects shows that severity of amnesia (as indexed by standard tests, such as the Wechsler Memory Scale) is correlated with memory for new associations as revealed by an indirect test. Patients defined as "mildly amnesic" are more likely to show indirect memory for new associations than are patients defined as "severely amnesic" (Schacter 1985b; Schacter & Graf 1986b). Since severe amnesics would be expected to show poorer memory than mild amnesics on a direct test for new associations, this result is suggestive of a parallel effect of severity of amnesia on direct and indirect measures of association [but see also Moscovitch et al (1986), who found memory for new associations in severely memory-disordered patients, using a reading-speed measure].

This result might be taken to imply that indirect memory for new associations relies on explicit retrieval of associations; such explicit retrieval would be more likely to occur in mild amnesics than in severe amnesics. However, amnesics who perform normally on an indirect test of a new association can show floor-level performance on a direct test of recall for the same association (Graf & Schacter 1985, data from unrelated pairs). Additionally, normals (and also amnesics, if they are given study pairs whose members are related) produce a substantial number of responses in cued recall that they did not produce in the same-context condition in a previous test of word completion. This result suggests that indirect tests of association are not simply more sensitive tests than are direct tests of association, because success on a less Annual Reviews www.annualreviews.org/aronline

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sensitive test (e.g. cued recall) implies that a more sensitive test could also be passed (Graf & Schacter 1985). New associations can be termed "implicit" when indirect measures of those associations are dissociated in this manner from direct measures for the same associations.

*Encoding and interference effects* An indirect test will reveal an association between two previously unrelated words only when the subject has encoded those words semantically and in a meaningful relation to one another. It will not reveal an association if the encoding task consists of (a) comparing the members of the pair with respect to some structural feature, such as number of vowels (Graf & Schacter 1985); (b) processing each word semantically (e.g. pleasantness rating), but not in relation to the other member of the pair (Schacter & Graf 1986a); or (c) reading the pair of words as part of an anomalous sentence, such as "the *ROCK* was returned to the *CANDLE*" (Schacter & Graf 1986a). Memory for an association as revealed in a direct test is also poor if the to-be-remembered response word is not processed in a meaningful relation to the stimulus word (Graf & Schacter 1985; Schacter & Graf 1986a); in this respect direct and indirect tests of new associations behave similarly.

However, direct and indirect tests of new associations are dissociated when the degree of semantic elaboration of the relationship between the members of a pair of words is manipulated. The advantage of the same- over the differentcontext condition in word completion remains the same (a) whether the subject generates a single word or a complete sentence linking the members of a pair, and (b) whether the subject rates a sentence according to how well it relates the two words or generates a sentence linking the words. By contrast, when told to use stems of response words to retrieve studied responses (a direct test), the subject benefits much more from reinstatement of the stimulus term of the pair when she/he previously generated a complete sentence relating the two items than when she/he generated a word linking the items or read a sentence linking the items (Schacter & Graf 1986a).

 weaker when two responses had been associated with a stimulus than when one response had been associated with a stimulus (i.e. standard proactive and retroactive interference effects were obtained). This selective effect of interference on a direct test for new associations also occurred when the direct test was a pair-matching test or a modified-modified free-recall test.

REPETITION PRIMING VERSUS ASSOCIATIVE MEMORY As noted above. severely amnesic patients were impaired on both direct and indirect tests of memory for new associations (Schacter 1985b; Schacter & Graf 1986b), whereas mildly amnesic patients were impaired only on direct tests of new associations; by contrast, both severely and mildly amnesic patients showed intact repetition priming effects. Repetition priming effects also differ from direct and indirect manifestations of associative memory in that the same amount of priming is obtained regardless of LOP or degree of elaborative or associative processing at study (Graf & Schacter 1985; Schacter & Graf 1986a; see review above). However, repetition priming seems to share immunity to interference with indirect tests of associative memory. Jacoby (1983a) found no reduction in perceptual identification priming across five study-test trials conducted on consecutive days (i.e. there was no proactive interference); additionally, the number of study-test trials intervening between study and test of a list did not influence the magnitude of priming (i.e. there was no retroactive interference). Perceptual identification priming also does not appear to be susceptible to intralist interference effects (list-length effects). Merickle (unpublished data cited in Jacoby 1987) found no difference in priming between a condition in which 500 words were studied and a condition in which 100 words were studied.

Although direct priming effects do not seem to be susceptible to interference in the traditional sense of the word (i.e. interference between items encoded in a similar spatiotemporal context), interference might occur between items encoded similarly on dimensions other than spatiotemporal ones. For example, if a subject studied OFFEND on a first list and OFFICER on a second list, then later completed the stem OFF\_ \_, it seems likely that the two primed words would compete as responses to the same cue, inhibiting priming in comparison to a single-list control condition. Mayes et al (1987) provide intriguing results relating to this hypothesis. They presented A-B (e.g. bee-WASP) and A-C (e.g. bee-HONEY) lists to amnesic and control subjects. In one condition, subjects received a cued-recall test for A-C pairs following presentation of the two lists; in another condition, a free-association test was given (e.g. *bee-???*). Consistent with past results, production of C responses in cued recall was better for controls than for amnesics, and amnesics' poor performance could be attributed to intrusions of B responses. By contrast, both amnesics and controls performed similarly under freeAnnual Reviews www.annualreviews.org/aronline

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association instructions, both producing similar numbers of B ("intrusions") and C ("correct") responses. This result suggests (a) that cued recall performance in amnesics reflects implicit memory, because amnesics suffered the same amount of proactive interference under cued recall and free-association instructions, and (b) that two high associates of a cue word, when both primed, will compete as responses to the cue word in a free association test in both normal and amnesic subjects.

### Role of the Linguistic Unit

Comparisons of stimuli that possess memorial representations prior to the experiment with those that do not are occupying an increasingly central position in research on the relation between implicit and explicit memory. Examples are the comparison of word and nonword stimuli, and the comparison of two-word compounds that behave linguistically as a unit (e.g. nominal compounds like stumbling block) with those that do not (e.g. noun phrases like copper block). Stimuli that have preexperimental representations are assumed to be chunked (e.g. Wickelgren 1979), codified (Salasoo et al 1985), or unitized (e.g. Hayes-Roth 1977; Schacter 1985a). A codified representation "responds as a single unit to a set of features and serves to label, code, name, or identify those features" (Salasoo et al 1985, p. 51). A number of studies now indicate that the occurrence or nonoccurrence of dissociations between direct and indirect measures depends critically on whether the stimuli used possess codified representations. These data have important implications for the debate between abstractionist and nonabstractionist views of implicit memory.

Comparisons of repetition priming with word and nonword stimuli have been numerous. Lexical decision studies (which necessarily include both word and nonword stimuli) have yielded inconsistent results, some showing nonword repetition effects (e.g. Dannenbring & Briand 1982; Kirsner & Smith 1974; Moscovitch 1985; Scarborough et al 1977) and others failing to find such effects (e.g. Forbach et al 1974; Ratcliff et al 1985). When nonwords do show a repetition effect in lexical decision, it is smaller than that observed for words, and it decays rapidly as the interval between the two presentations of the item increases. Since nonwords have no memorial representation prior to the experiment, this pattern of findings has been taken to imply that repetition priming with words primarily reflects modification of the state of a stable lexical representation and that nonword repetition effects, when they are observed, reflect contamination from nonlexical factors (e.g. Monsell 1985). Indeed, the original connotation of the term "priming" was that the primed item possesses a memorial representation prior to the priming event (Jacoby & Brooks 1984).

In contrast to the lexical decision results, it has been known for some time

that repetition of pseudoword stimuli enhances perceptual identification of those stimuli (e.g. Feustel et al 1983; Jacoby & Witherspoon 1982; Johnston et al 1985; Postman & Rosenzweig 1956; Solomon & Postman 1952). Feustel et al (1983) argued that the discrepancy between the lexical decision and identification paradigms results from an inherent property of lexical decision: Repeated nonwords are to be rejected by the subject as nonwords; however, repetition may confer word-like properties upon nonwords, so that there would be conflicting tendencies to accept repeated nonwords as words and reject them as nonwords. Consistent with this hypothesis is the McKoon & Ratcliff (1979) finding of inhibition for repeated nonwords in lexical decision [see also Forster & Davis (1984) for a similar small effect]. Monsell (1985) found a nonword repetition effect in lexical decision when the interval between the decision response and the presentation of the next item was 1 sec. but not when it was 0.5 sec. He argued that subjects learned the relationship between the specific nonword and the "no" response better in the former condition than in the latter. Thus it is possible that the inconsistency of nonword repetition effects in lexical decision is the result of a varying trade-off between improved response learning and increasing word-likeness of the stimuli. In sum, the difference between word and nonword priming effects in lexical decision does not support the notion that repetition priming primarily reflects alteration in the state of a preexisting memory representation.

Feustel et al (1983) developed a latency measure of perceptual identifiability by having subjects terminate a gradually clarifying stimulus when they believed they could identify it (*continuous threshold latency identification*, CTLI). In CTLI, words were identified faster than pseudowords, and both words and pseudowords benefitted approximately equally from repetition in the experiment, over a small range of number of repetitions (1, 2, or 3 presentations/item). Using Sternberg's (1969) logic, Feustel et al argued that this approximate additivity ruled out the idea that the locus of the repetition effect was a preexisting memory representation; instead, processes common to the identification of words and pseudowords must produce the repetition effect. The overall superiority of words over pseudowords was attributed to the presence of a unitized code that made a response readily available.

The unitized-code concept also accounts for the variation in the difference between word and pseudoword performance as a function of the type of identification task. The advantage of words over pseudowords in accuracy is large in the traditional perceptual identification situation, in which the stimulus is briefly presented before a mask. By contrast, when the stimulus is gradually clarified before presentation terminates, the word advantage is reduced (Feustel et al 1983; Salasoo et al 1985). Feustel et al (1983) argue that the presence of a discrete and automatic identification response to a stimulus

is important in the former situation because perceptual information decays rapidly while the subject is trying to construct a response. When the stimulus is gradually clarified, perceptual information is constantly restored while the subject attempts to construct a response, so the presence of a ready response to a stimulus is not so important.

Feustel et al's argument for the noninvolvement of unitized representations in repetition priming has difficulty dealing with the data on word and nonword repetition in memory-disordered subjects. When these subjects study a pseudoword, such as *numdy*, they show no priming when later given *num* and asked to generate a completion (Diamond & Rozin 1984), and their later perceptual identification of that item is not significantly facilitated (Cermak et al 1985). In sum, the memory disorder produces parallel impairments on indirect tests when nonword stimuli are used. If the processes producing repetition priming are common to words and nonwords, there is no reason to expect impaired priming when nonwords are used.

Consistent with the word/nonword data from amnesics, Rugg (1987) found that changes in event-related potentials that occur with repetition of specific stimuli were different for words and nonwords in normal subjects. Additionally, dependence between recognition memory and perceptual identification is found in normal subjects when nonword stimuli are used (Jacoby & Witherspoon 1982; Johnston et al 1985), when independence is found with the same procedure (test order etc) with word stimuli. This result suggests that priming effects with nonword stimuli rely on some of the same processes that are recruited by direct tests of memory; amnesics, who are impaired on direct tests, would then be expected to be impaired on nonword priming.

Schacter (1985a,b; Glisky et al 1986a,b; Schacter & Glisky 1986) has argued that preserved priming in amnesics is critically dependent on the provision at test of a part of a stimulus that has a unitized memorial representation. Glisky et al (1986a) presented subjects with the definition of a target word; the subject was then given a stem corresponding to that word and asked to generate the appropriate response. As trials progressed, memorydisordered subjects learned to produce the appropriate response with fewer and fewer letters of the response word provided. However, they experienced inordinate difficulty (compared with controls) in making the transition from producing the word with one letter provided to producing it with no cue letters. When the task consisted of learning pairs of unrelated words using this *method of vanishing cues*, the difficulty in making the transition from the one-letter stem to no letters was even more acute than with definitions (Schacter 1985a).

Schacter's arguments are more directly confirmed by studies of cued recall and free-association priming with unitized and non-unitized word pairs. In a study by Schacter (1985a; see also 1985b), unitized pairs were common idioms, such as sour grapes and small potatoes; non-unitized pairs were created by re-pairing the elements of the idioms (i.e. sour potatoes, small grapes). After studying unitized and non-unitized pairs, subjects were given a free-association test, then a cued recall test. In free association with unitized pairs severe amnesics displayed the same level of priming as did matched controls; in the subsequent cued recall test the amnesics produced no more responses than they had produced in free association, whereas controls produced twice as many in cued recall as in free association. By contrast, both controls and amnesics produced essentially no list-words in free association for the non-unitized pairs. Amnesics were also unable to produce any responses from these pairs in cued recall, whereas controls were able to recall a substantial proportion of the responses. Amnesics demonstrate knowledge of an association between two previously unrelated words only when the stem of the response word is provided and the test for the association is indirect (Graf & Schacter 1985; Schacter & Graf 1986b). When memory-disordered patients perform quite well on cued recall tests, the members of the pairs must be highly related, and the patients do not produce any more list words than they produce in an indirect test such as word completion or free association (e.g. Diamond & Rozin 1984; Graf et al 1984; Mayes et al 1987; Schacter 1985a; Shimamura & Squire 1984).

Non-unitized word pairs also present an exception to the generalization that repetition priming is independent of study LOP or elaboration in normal subjects. When North American subjects were tested with unfamiliar British idioms (e.g. *curtain lecture*) or unrelated word pairs, the likelihood of producing a list-word was higher for elaborative than for nonelaborative study processing for both free-association and cued recall tests. By contrast, free-association priming is independent of study processing for familiar idioms and highly related paired associates (Schacter & Whitfield 1986). As with dependence between recognition and perceptual identification for nonwords, these data could be taken to imply that indirect test performance (in this case free association) with non-unitized stimuli relies on processes that are used in direct tests.

The important role of preexisting linguistic units in priming is further emphasized by Osgood & Hoosain's (1974) results with nominal compounds. They used nominal compounds (e.g. *stumbling block*), noun phrases (e.g. *copper block*), and nonsense phrases (e.g. *sympathy block*). Nominal compounds resemble the idioms used by Schacter in that the meaning of the compound cannot be predicted from knowledge of the meaning of either of its parts in isolation. Osgood & Hoosain initially demonstrated that visual duration thresholds (VDTs) for nominal compounds were the same as those of single words matched in length and frequency, suggesting that nominal compounds behave as units in identification. In the experiment of most

interest here, initial identification of compounds was best for nominal compounds, next best for noun phrases, and worst for nonsense phrases. In the next phase, individual words from previously presented compounds were presented. In contrast to the results for whole-compound identification, VDTs for individual words were higher for words from nominal compounds than for words from noun phrases or nonsense phrases (thresholds for the latter two phrase types were not different). In a subsequent free-recall test, nominal compounds and noun phrases were equally well recalled, and both were better recalled than nonsense phrases.

The dissociations observed among VDTs for compounds, VDTs for individual words, and free recall mean that the superiority of noun phrases and nonsense compounds over nominal compounds in priming of VDTs for individual words cannot be explained by differences in identifiability or recallability of the compounds themselves. It is also important to note that the similarity between the physical form of the stimulus between initial presentation of a compound and later test of its components was identical for all three types of compounds; therefore views of priming that emphasize the role of perceptual similarity between study and test stimuli (e.g. Jacoby 1983b; Roediger & Blaxton 1987a,b) are not sufficient to explain the results. Instead, it seems that the additional notion of codified representations is necessary.

Transfer between study of unitized compounds and tests of their subunits and between study of subunits and tests of compounds seems to be asymmetrical. Whereas study of nominal compounds does not reduce later VDTs for components of those compounds, study of the components does reduce later VDTs for the entire compound (Osgood & Hoosain 1974). Similarly, studying one of the component nouns of a compound noun facilitates a later lexical decision concerning the entire compound (Monsell & Conrad, in Monsell 1985), whether that compound is transparent (e.g. *beanpole*), opaque (e.g. *butterfly*), or a pseudocompound (e.g. *boycott*). Such asymmetries are again difficult to account for with the notion of sensory-perceptual overlap, because the overlap between study and test cues is identical. For example, study of *stock market* and test of *market* involves the same degree of study-test overlap as does study of *market* and test of *stock market*.

Transfer is sometimes found between words that are structurally but not morphologically or semantically related, such as words that share graphemes (e.g. Evett & Humphreys 1981; Feustel et al 1983; Shulman et al 1978) or phonemes (Hillinger 1980; Mandler et al 1986). However, it seems unlikely that the literature on priming between morphologically related words can be explained in terms of overlap between perceptual or structural features; instead, morphemic codes must be postulated that are common to the words that facilitate each other (e.g. Feldman & Fowler 1987; Fowler et al 1985; Henderson et al 1984; Kempley & Morton 1982; Murrell & Morton 1974; Stanners et al 1979; for a summary, see Henderson 1985). Additional support for the role of codified representations in priming comes from priming studies in which there was no perceptual overlap between study and test cues (Shimamura 1986): In free association, studying a strong associate (e.g. *chair*) of a test cue (*table-?*) enhances the likelihood of generating that associate to the cue, even if the cue was not itself studied with the associate in the priming phase (Shimamura & Squire 1984). A similar effect is obtained in category generation when category exemplars are studied in the absence of the category label, and the category label is used as a test cue (Graf et al 1985).

The contrast between Schacter's (1985a) results with idioms and Osgood & Hoosain's results with nominal compounds is suggestive of an interesting dissociation between priming measures that results from the interaction of the type of priming unit with the type of testing unit. When the test permits subjects to redintegrate a compound (as in free association), priming is found with prior study of unitized compounds and not with prior study of nonunitized compounds (Schacter 1985a). By contrast, when the test depends on redintegration of subunits of compounds (such as in individual word identification) prior study of non-unitized compounds yields superior priming to study of unitized compounds (Osgood & Hoosain 1974).

### Retention Interval and Cuing Conditions

Retention interval effects have been cited as providing a basis for differentiating direct from indirect tests of memory (e.g. Jacoby & Dallas 1981; Tulving 1983, 1984a). Such claims are often based on instances in which priming shows no significant decrease over a particular retention interval, whereas a direct memory measure shows a significant decrease in performance over the same interval. Some of these instances involved manipulations of interval between study and test presentations within an experimental session (e.g. perceptual identification: Feustel et al 1983; lexical decision: Moscovitch 1985; Scarborough et al 1977). In other instances study and test phases took place in different sessions and the intervals involved were large, such as 24 hr (perceptual identification: Jacoby & Dallas 1981), and 7 days (fragment completion: Komatsu & Ohta 1984; Tulving et al 1982).

However, priming measures rarely defy the law of forgetting over periods of days or weeks. Jacoby (1983a) and Salasoo et al (1985) found decreases in perceptual identification priming over 24 hr, and Scarborough et al (1977) found a 24-msec repetition effect in lexical decision after 2 days, whereas the within-session repetition effect was 64 msec. Decreases in fragment completion priming have been reported over 7 days (Roediger & Blaxton 1987a,b), and from 7 days to 5 weeks (Komatsu & Ohta 1984). Moreover, whether within-session lag effects are observed can depend on the lags considered. Repetition priming in lexical decision shows a very short-term facilitation that

decays when one or two other items intervene between the presentations of an item, leaving a longer-term priming effect that is relatively constant across within-session lags (Monsell 1985; Ratcliff et al 1985) but declines slightly over large values of lag (e.g. Scarborough et al 1977). In sum, immunity to forgetting for indirect measures is not well replicated and depends on the particular range of intervals considered in the study.

Indirect measures often seem to show slower decay over a particular retention interval than do direct measures; however, interpretation of these cases is complicated by scale differences between the two types of measure. There are only a few cases in which an argument for the direct comparability of measurement scales might be made, such as in lexical decision/recognition comparisons, in which the same stimuli and response sets are used, and the dependent variable is always reaction time. Unless measurement scales are directly comparable, only a limited subset of the possible interactions between test and retention interval (e.g. crossover interactions) can be taken as evidence for differential forgetting between tests (for a list of such interactions, see Loftus 1978).

One might rely on the more qualitative argument that tests of indirect memory show very persistent effects, in contrast to the typical lability of memory as revealed by direct tests. In all the above studies, priming effects were still significant at the longest interval studied. Effects of prior exposure on affective preference persisted at a week (Seamon et al 1983b). Savings in reading geometrically transformed text have been found at 2 weeks (Moscovitch et al 1986) and at 3 months (Cohen & Squire 1980) in memory-disordered subjects, and at a year in normal subjects (Kolers 1976). Savings in maze learning, jigsaw puzzle assembly, and pursuit rotor performance persisted at a week in Korsakoff amnesics (Brooks & Baddeley 1976), and patient H. M. displayed savings in the Tower of Hanoi puzzle after a year (Cohen 1984).

However, extreme persistence of memory as revealed in indirect tests is not general. Repetition priming in free association and in word completion (in which stems can be completed as at least 10 different words) has consistently been found to decay rapidly, reaching baseline at about 2 hr in both normal and amnesic subjects (e.g. Diamond & Rozin 1984; Graf & Mandler 1984; Graf et al 1984; Mayes et al 1987; Shimamura & Squire 1984; Squire et al 1987). In the same studies, tests of recognition memory given to normal subjects still show well-above-chance performance at a 2-hr delay. Salasoo et al (1985) found no advantage of old over new words in perceptual identification a year after initial study, even though old words were still recognized at above-chance level.

In sum, the most that can be said based on retention interval data is that direct and indirect measures are sometimes independent as a function of retention interval; that is, one type of measure sometimes shows evidence of memory at a particular retention interval when the other type does not. However, a general classification of the different measures based on resistance to forgetting is not possible (a) because scale differences often preclude comparison of forgetting rates across direct and indirect measures, and (b) because forgetting rates within the two classes of measures are extremely variable.

Factors accounting for variability in persistence of priming in indirect tests have not been extensively investigated, although knowledge of such factors is critical to explanations of priming. However, a few extremely interesting results suggest the importance of encoding conditions, materials, and cuing conditions at test:

1. Forster & Davis (1984) masked the first presentations of repeated stimuli in the lexical decision paradigm, reducing the role of attention in the initial encoding of an item. Priming decayed rapidly as a function of the number of items intervening between first and second presentations of a word, reaching chance when 17 items intervened. This decline in priming over a short interval is in contrast to the persistence of priming over similar or much larger lags observed in other lexical decision studies (e.g. Kirsner & Smith 1974; Monsell 1985; Ratcliff et al 1985; Scarborough et al 1977) and suggests the role of attention at encoding in producing long-lasting priming effects.

2. In perceptual identification, Salasoo et al (1985) found that old pseudowords that had received numerous repetitions at initial study were identified better than new pseudowords in a test given a year after initial study. As noted above, no repetition effects over a year were obtained with words in the same study; both old and new words were identified as well as old pseudowords. This result suggests that study procedures that lead to codification of previously poorly integrated items will produce long-lasting differences between studied and nonstudied items, because nonstudied items do not have the advantage of codification.

3. Schacter & Graf (1986a) obtained above-chance word completion priming in a 24-hr test by reinstating a word that had been associated with the to-be-completed word when it was studied. When the associate of the to-becompleted word was not reinstated, no priming was observed, as would be expected based on the word completion data discussed above. This result suggests that reinstatement of local contextual conditions present at encoding can retard the decay of priming.

The role of cuing conditions in retention interval effects has been systematically investigated by Squire et al (1987). They hypothesized that the persistence of priming in completion tests (such as word completion and fragment completion) was inversely related to the number of possible completions of the test cue. Using the word stems that are typically used in word completion

studies (which have at least 10 possible completions) they obtained the typical pattern, with priming at chance 2 hr after study. With word stems (e.g. *JUI*\_\_\_\_\_\_ for *JUICE*) or word fragments (e.g. *A*\_\_\_\_*A*\_\_\_*IN* for *ASSASSIN*) susceptible to only one completion, priming effects in normal subjects persisted at 4 days (although a decrease in priming was observed from an immediate to a 4-day test).

This result is plausible, given that graphemic cues that define smaller nonsemantic sets are more effective in both perceptual identification and graphemically cued recall (Nelson & McEvoy 1979b, 1984; Nelson et al 1984); however, it is complicated by the fact that LOP effects were observed in both word and fragment completion for normal subjects (with a semantic orienting task yielding superior performance to a nonsemantic task), suggesting the involvement of conscious retrieval strategies in the completion tests. Squire et al (1987) claim that their data show that long-lasting priming effects depend on conscious retrieval strategies, such as those used in recall. However, this claim is at variance with the large number of results showing that semantic processing is not necessary for long-lasting priming effects (reviewed above). Indeed, study activities that emphasize the perceptual characteristics of study items are beneficial for tests such as fragment completion, whereas they often result in poor performance in direct tests (e.g. Blaxton 1985; Jacoby 1983b; Roediger & Blaxton 1987a).

The Squire et al results from amnesics are much more impressive, since the indirect-test performance of amnesics is rarely, if ever, influenced by explicit memory. Priming declined to chance at 2 hr after study regardless of whether a test cue could be completed ten different ways or just one way. These results stand in marked contrast to the long-lasting priming effects obtained in other studies using normal subjects and cues that were susceptible to only one completion (e.g. Komatsu & Ohta 1984; Roediger & Blaxton 1987a,b; Tulving et al 1982). It appears, therefore, that long-lasting priming effects in normal subjects can be based on a form of information that is not available to amnesics. However, this conclusion does not imply that the form of information in question also supports performance in tests such as recognition and free recall. Instead, it is possible that normals gain implicit access to such information via graphemic or perceptual cues, and that such access is uncorrelated with access to the study episode in the sense in which it is required in recall and recognition. We elaborate on this view of priming effects below.

### CONCLUSIONS

### Interpreting the Data Pattern

The results reported above support Shoben & Ross's (1986) claim that "any successful theory must account for the pattern of dissociations and failures to

obtain dissociations" (p. 569). As they point out, the debate between abstractionist theorists and their critics has to some extent involved stacking dissociations between direct and indirect measures (which are assumed to support abstractionist positions) against nondissociations (which are assumed to call abstractionist positions into question). An example is the McKoon et al (1986) critique of the episodic-semantic distinction, in which one strategy employed is to question the validity and replicability of dissociations reported by Tulving (1983, 1984a). Our review suggests that this strategy is misconceived, because abstractionist positions derive support from parallel effects as well as dissociations, and nonabstractionist positions derive support from dissociations as well as parallel effects. For example, the deficit obtained in both recognition and perceptual identification in amnesic subjects when pseudoword stimuli are used supports abstractionist positions. This parallel effect is predicted because priming is assumed to depend on activation of an abstract representation, which is lacking for pseudoword stimuli. On the other hand, when priming tests show greater sensitivity to match between the precise physical form of study and test stimuli than do direct tests (a dissociation), abstractionist theories of priming are undermined because information about events resulting in priming is assumed to be lost, and direct tests are assumed to rely on recovery of study context.

DIRECT/INDIRECT AS A PREDICTOR Both abstractionist and nonabstractionist theories regard the distinction between direct and indirect measures as important. The direct/indirect distinction is useful in understanding differences between tasks and forms of measurement; further, recent comparisons of direct and indirect tests are of great importance to attempts to integrate theory across cognitive subdomains. Our review suggests, however, that the direct/indirect distinction performs poorly as a predictor of dissociations and nondissociations. Although there are a number of clear dissociations between direct and indirect tasks, there are at least as many examples of parallel effects, and of complex patterns in which the occurrence/nonoccurrence of dissociations varies systematically as a function of a critical variable.

The complexity of the data pattern across direct and indirect tests is complemented by an equally complex picture of dissociations and parallel effects within the direct and indirect classes of test. Dissociations between recognition and free recall measures (e.g. Anderson & Bower 1972, Expt. 3) and between recognition and cued recall measures (e.g. Tulving & Thomson 1973; Tulving & Wiseman 1975) were central to the classical theories of performance on direct tests (namely, generation-recognition theory and the encoding specificity principle). Comparisons of free recall, cued recall, and recognition have subsequently revealed a highly complex pattern of interrelations. For example, Tulving (1983, Ch. 11) summarized experiments that show dissociations between cued recall and free recall, and Gillund &

Shiffrin (1984) offered a comprehensive quantitative model of the effects on recognition and recall of a number of traditional independent variables, some producing parallel effects on the two measures, others producing dissociative effects. Most pertinent to the issues discussed here, contextual manipulations dissociate free and semantically cued recall from graphemically cued recall (as reviewed above; Blaxton 1985; Roediger & Blaxton 1987a). Additionally, Hirst et al (1986) found that amnesics were impaired in comparison to controls on a recall test, even when recognition performance between amnesics and controls was experimentally equated.

Research on lexical and conceptual organization has relied increasingly on task comparisons. Most prominent are comparisons of lexical decision and naming latencies (e.g. de Groot 1985; Hudson & Bergman 1985; Lupker 1984; Seidenberg et al 1984; for a summary, see Johnson & Hasher 1987). Other tasks compared with lexical decision include category verification (e.g. Balota & Chumbley 1984; Smith 1984), free association (Chumbley & Balota 1984), object and reality decision (e.g. Kroll & Potter 1984), and word retrieval (Bowles & Poon 1985). The relationships between these measures are again complex. Given this background, we should not be surprised by instances of dissociations between different measures of priming (Witherspoon & Moscovitch, cited in Moscovitch et al 1986), between priming and skill learning (Butters 1987), between cognitive skills such as reading and naming the letters of inverted text (Kolers & Magee 1978), and between objective task performance and verbalizable knowledge about that task (e.g. Berry & Broadbent 1984; Cohen et al 1985; Lewicki 1986). To this list of dissociations between indirect measures, we can add those between fragment completion and general knowledge retrieval (Blaxton 1985; Roediger & Blaxton 1987a), between word-fragment and picture-fragment completion (Roediger & Weldon 1987; Weldon & Roediger 1987), and between repetition priming and priming by new associates (Schacter & Graf 1986a,b), all described above.

As more and more comparisons between measures of memory are made, the complexity of the overall data pattern increases enormously and the important aspects of the data become more difficult to assimilate. On the other hand, we come closer to forming an overall image of the functioning of the memory system. Our task could be likened in some respects to finding the important dimensions of variation in a set of data, as in multivariate analysis. Isolating substages of different tasks must become increasingly important in determining which dissociations and parallel effects are of theoretical importance. As Shoben & Ross (1986) point out, simply enumerating dissociations and parallel effects is unlikely to result in progress unless we gain some insight into the nature of the processes that are being differentially or similarly affected. Shoben & Ross suggest that progress on this enterprise might be made by combining dissociation methodology with additive-factors methodology to specify the locus of differential effects. Unfortunately, use of additive-factors methods assumes that the tasks being compared possess directly comparable measurement scales. As pointed out above, this assumption is rarely, if ever, justified in task-comparison experiments. Nevertheless, the emphasis on analysis of component processes that can be found in work on semantic priming and lexical access (e.g. attempts to untangle automatic and strategic contributions to semantic priming; comparisons of lexical decision and naming) could profitably be incorporated into work comparing direct and indirect memory measures. In this vein, it is urgent that explicit (strategically based) and implicit contributions to repetition-priming effects be teased apart, because our knowledge of the relative contributions of these factors is critical to our theoretical interpretation of parallel effects on direct and indirect memory tests.

PROBLEMS IN INTERPRETING PARALLEL EFFECTS As we noted at the outset, there are two ways of interpreting parallel effects on direct and indirect memory tasks. The first is to assume that both implicit and explicit forms of memory are affected in a similar way by particular variables. This seems to be the conclusion that Jacoby (1983a, 1987; Jacoby & Brooks 1984) wants to make; the point of demonstrating that direct and indirect tasks are affected similarly by variables such as repetition, attention, and list context was to demonstrate that both explicit and implicit forms of memory depend on memory for prior episodes. However, this conclusion is underdetermined by the data unless explicit memory is identified with performance on direct tests and implicit memory is identified with performance on indirect tests. We have argued that this assimilation of forms of memory to methods of testing is inappropriate and begs important questions.

The occurrence of parallel effects is equally compatible with a second interpretation, namely that direct and indirect tests sometimes share a form of memory that is being affected by the manipulation that is producing the parallel effect. For example, Schacter's (1985b) interpretation of Jacoby's (1983a) list-context data is that the manipulation of proportion of old words on the test list affected the likelihood that subjects would spontaneously use conscious retrieval strategies to enhance identification performance for old items. Similarly, effects of repetition and attention at encoding could be seen as influencing the likelihood that subjects notice repetitions of stimuli at test; noticing such repetitions might lead them to invoke conscious strategies to enhance processing of repeated items. The superiority of generation over reading in recall and general knowledge tests (Blaxton 1985; Roediger & Blaxton 1987a) could be explained by assuming that subjects spontaneously

used explicit memory for studied items to arrive at answers on the general knowledge test.

A number of other investigators have argued that observed repetitionpriming effects can be due to implicit memory but that use of a conscious strategy can increase the amount of priming observed (e.g. Clarke & Morton 1983; Cohen 1984; Diamond & Rozin 1984; Forster & Davis 1984; Fowler et al 1985; Graf et al 1984; Johnson et al 1985; Monsell 1985; Moscovitch et al 1986; Squire et al 1987). Such arguments are often used to explain cases in which a memory disorder is associated with parallel deficits on a direct and an indirect task; that is, it can be assumed that the deficit shown by memorydisordered patients on the indirect memory test is due not to a deficit in implicit memory processes but to the spontaneous use of conscious retrieval strategies by control subjects that are not available to memory-disordered patients (e.g. Cohen 1984; Moscovitch et al 1986; Schacter 1985b; Squire et al 1987). Demonstrating impaired indirect test performance in memorydisordered subjects involves the use of two etiologic groups, of which one shows normal indirect test performance and the other shows impaired performance (e.g. Shimamura et al 1987).

Views that attribute priming in normals to a combination of implicit and explicit forms of memory have problems handling the data showing interactions between encoding manipulations and test conditions. Elaboration and LOP at study produce strong effects on direct tests but no effect on indirect tests. Generating study items as opposed to reading them improves free recall but reduces priming in perceptual identification (Jacoby 1983b) and fragment completion (Blaxton 1985; Roediger & Blaxton 1987a). If priming sometimes involved access to conscious memories, why would priming effects not be larger for words that are well remembered on direct tests of memory (i.e. deeply processed and generated items) than for items that are poorly remembered? Additionally, Jacoby's perceptual identification studies (1983a,b; Jacoby & Dallas 1981; Jacoby & Witherspoon 1982) have consistently revealed very low rates of intrusion errors due to the production of study-list words. In the 1983a study, the probability of giving a list word as an incorrect response was .003, both in the condition in which 90% of test words had been studied, and in the condition in which only 10% of test words had been studied. These results rule out crude guessing interpretations of the contribution of conscious strategies to priming (but see Ratcliff & McKoon 1988 for a sophisticated bias theory of priming).

The data on parallel effects will remain difficult to interpret until we know more about the contribution of intentional explicit memory to performance on indirect tests. One possible strategy would be to look for stochastic independence or dependence in cases in which parallel effects are observed. If a parallel effect was accompanied by stochastic dependence between measures, it would suggest that the parallel effect was the result of a form of memory that was contributing to performance in both tests. If independence was observed, it would suggest that the manipulated variable was producing similar effects on different forms of memory. Such an analysis presumes, of course, that one can work around the effects (discussed above) that currently contaminate analyses of stochastic independence.

### Evaluation of Theoretical Positions

Schacter (1985a, 1987) presents incisive criticisms of abstractionist and nonabstractionist accounts of implicit and explicit memory. We briefly list the deficiencies and strengths of each position, borrowing liberally from his treatments, then outline what we take to be the essential components of an adequate position.

ABSTRACTIONIST POSITIONS These positions share the assumption that implicit memory results from a form of representation that is *ahistorical* (Monsell 1985) or *synchronic* (Henderson 1985); that is, it does not maintain information about the events that formed or modified that representation. Explicit memory depends on the formation of memory traces that encode specific details of prior experiences. The ahistorical form of representation is described as activation of a lexical or semantic representation (semantic/ episodic system view; logogen model; activation/elaboration view), or as formation and modification of cognitive and perceptual-motor procedures (procedural/declarative distinction).

Views that attribute implicit memory to activation of preexisting abstract lexical or semantic representations account well for dissociations in which a variable exerts a strong influence on a direct test but not on an indirect test (e.g. effects of LOP of study words in repetition priming). All that is necessary for priming is that a permanent representation is activated in the study phase. Activation views also account well for demonstrations of the importance of preexisting linguistic units in priming. For example, priming in amnesics depends critically on provision at test of a portion of a stimulus that has a preexisting memory representation, and does not occur with nonword stimuli.

When performance on a direct or an indirect test reveals the influence of newly acquired information, this influence, *ex hypothesi*, cannot be attributed to implicit memory; it must therefore be attributed to explicit memory. Activation views would therefore attribute nonword priming effects in normal subjects to explicit memory; however, they could not account for implicit memory for new associations in amnesics, or any other demonstrations of preserved memory for new information in amnesics (such as in studies of conditioning, and of cognitive and perceptual-motor skill learning). These

views also do not account for the dissociative effects of interference and degree of elaboration on direct and indirect tests for new associations in normals.

Because the notion of activation connotes the idea of autonomous decay over time, activation views fail to predict variability in the persistence of priming as a function of cuing conditions. Activation theorists might point to the Squire et al (1987) finding that priming in amnesics decayed to chance at 2 hr, regardless of the nature of the test cues. Priming in normal subjects that persists for days or years would then be attributed to the influence of explicit memory. However, this explanation runs afoul of the numerous cases in normal subjects in which a variable exerts a large effect on a direct test but not on an indirect test. It was this type of dissociation that initially suggested the plausibility of an activation account. Additionally, there are examples of long-lasting item-specific priming in amnesics (e.g. Cohen & Squire 1980; Moscovitch et al 1986).

The episodic-semantic distinction attributes memory for facts to the semantic system and memory for personal experiences to the episodic system; memory for personal experiences and memory for facts should therefore be dissociable. As numerous critics of the episodic-semantic distinction have pointed out, there is little evidence for such a dissociation. To cite two counterexamples to this prediction, priming in general knowledge retrieval is influenced in the same way as free and semantically cued recall by experimental manipulations (Blaxton 1985; Roediger & Blaxton 1987a), and memory for facts as well as for personal experiences is disrupted in both anterograde and retrograde amnesia (as reviewed above).

The procedural-propositional distinction suggests that memory for both experiences and facts should be impaired in amnesia, since both forms of knowledge are assumed to be propositional. It also accounts for dissociations in normals between task performance and verbalizable knowledge about that task. Unlike activation views, it accounts for new learning of cognitive and perceptual-motor skills in amnesics. Priming is treated as reflecting modification of the procedures used to deal with specific stimuli. Dissociations between skill learning and priming in memory-disordered subjects (Butters 1987) therefore cannot be accommodated, since these two classes of memory phenomena are supposed to reflect the operation of the same memory system. The absence of nonword priming in amnesics is also not predicted, because there is no reason why the procedures used to identify nonwords should not be modified by experience.

All abstractionist positions have difficulty dealing with effects on priming of match between study and test context, because the representations supporting priming are assumed to lose information about the priming episode. Activation models have been modified to account for some of these effects (e.g. Allport & Funnell 1981; Clarke & Morton 1983; Jackson & Morton 1984; Kirsner & Dunn 1985; Monsell 1985; Morton 1979, 1981). Modality effects in priming can be handled by postulating separate auditory and visual logogens. The superiority of reading over generating for later perceptual identification can be handled by assuming that generating material at study involves firing production logogens but not the receptive logogens that are later involved in identifying test words. This proliferation of modular input and output systems in response to data may be independently justifiable on philosophical grounds (e.g. Fodor 1983, 1985). However, even the modified logogen model cannot handle effects of subtle aspects of context on priming, such as typeface, letter case, etc. Activation theorists have often attempted to "explain away" such findings, which are generally nonsignificant at the level of the individual study but rather consistent across studies. We believe that it is no longer possible to ignore the consistent, if small, influence of subtle aspects of perceptual context on priming effects.

As Schacter (1987) points out, the NONABSTRACTIONIST POSITIONS strengths and weaknesses of Jacoby's episodic perspective and Kolers & Roediger's procedural perspective can be described as a mirror reflection of those of activation views. Priming of nonwords in normal subjects, effects of match between study and test context on priming, and dependence of priming on new associations are all accommodated. Further, the distinction between data-driven and conceptually driven tasks permits an account of the effects of perceptual and linguistic context that accommodates both parallel and dissociative effects across direct and indirect memory tests. Because forgetting in both direct and indirect tests is construed as being cue-dependent (Tulving 1974), these positions can account for the variability in persistence of memory as revealed by different direct and indirect memory tests. In particular, they can account for greater persistence of completion priming with cues that uniquely specify their completions than with cues that can be completed multiple ways. The former type of cue results in more unique feature overlap between the test cue and the study episode than does the latter. Uniqueness of cue-trace feature overlap is an important determinant of memory in direct tests (e.g. Craik & Jacoby 1979; Eysenck 1979; Fisher & Craik 1977; Jacoby & Craik 1979).

Difficulties for the Jacoby and Kolers & Roediger positions are created by the important role of preexisting linguistic units in priming. For example, it is not clear why free-association priming should be found for unitized phrases but not for non-unitized phrases. It is also not clear why preserved priming in amnesics should be so dependent on provision of part of a preexisting unit at test, and why amnesics do not show priming with nonwords. If priming in amnesics results from implicit access to traces that are specific to particular

episodes, it is not clear why amnesics, unlike normals, show the same decay rates in completion priming whether cues can be completed multiple ways or only one way. Finally, it is not clear why implicit memory for new associations is elaboration dependent, when repetition priming is not so dependent. This finding argues strongly against the view that effects of new associations in word completion and other indirect memory tests are simply due to reinstatement of a perceptual gestalt that was present at study.

Ratcliff & McKoon (1988) have proposed a nonabstractionist model [adapted from the recognition model of Gillund & Shiffrin (1984)] designed to handle effects of new associations on performance in indirect and direct memory tests. The model assumes that context cues and target stimuli are combined into a compound cue. When context cues and target items are experimentally or preexperimentally related, the familiarity of this compound cue is higher than when context and target are residually related; and performance is consequently facilitated. This model accommodates McKoon & Ratcliff's (1979, 1986; McKoon et al 1986; Ratcliff & McKoon 1981, 1986) claims concerning the similarity (time course, automaticity) of episodic and semantic priming effects. The debate over episodic priming effects in direct and indirect memory tests (e.g. Carroll & Kirsner 1982; Durgunoğlu & Neely 1987; Neely & Durgunoğlu 1985) is supposed to address McKoon & Ratcliff's claim that direct and indirect tests rely on the same type of information.

However, our review suggests that this debate is based on mistaken premises, for two reasons. First, priming by new associations definitely occurs, and can be implicit (i.e. unconscious/automatic) because it occurs in amnesics (although for methodological reasons it may be difficult to demonstrate in lexical decision with normal subjects). Second, what is really at issue is whether the representations and processes that support priming due to a new association in an indirect test are the same as those that support retrieval of that same association in a direct test, such as cued recall. It remains to be seen whether the Ratcliff & McKoon (1988) model can accommodate the differential effects of amnesia, interference, and degree of elaboration on retention of new associations as measured by direct (e.g. cued recall) and indirect (e.g. word completion) tests. It is also not clear that Ratcliff & McKoon's (1988) bias explanation of repetition priming could handle the effects of perceptual and linguistic context on repetition priming.

## Components of an Adequate Theoretical Position

The complexity of the current data pattern suggests that an adequate explanation of the relationship between implicit and explicit memory needs to incorporate components of both abstractionist and nonabstractionist theory. In particular, it seems necessary to postulate at least two sources of implicit memory—ahistoric traces that depend on preexisting codified representations, and historic traces that incorporate contextual information. Whether the latter, "episodic," type of trace supports explicit or implicit memory depends on task demands and the nature of the retrieval cues available (cf the dual-access position of Jacoby and others).

These two components of implicit memory seem necessary to account (a) for the rapid decay of priming under some conditions, and for the dependence of priming on preexisting codified units; and (b) for the persistence of priming under other conditions, for priming with new information (nonwords, new associations), for the contextual specificity of priming, and for the variations in performance on direct and indirect tests as a function of the type of test processing (data-driven vs conceptually driven). In overall character, such a hybrid position seems to us to be closest to that proposed by Schacter (1985a), although it is couched in somewhat different terminology.

Proposing a hybrid position that combines "activation" (abstractionist) and data-driven/conceptually driven processing (nonabstractionist) perspectives is an obvious but less than satisfying response to Schacter's (1987) observation that the virtues and shortcomings of the two perspectives are mirror-images of each other. It is less than satisfying because a hybrid position, simply by incorporating more theoretical constructs than the simpler positions, is bound to fit the data better than either simpler position does. Even with those constructs, however, significant difficulties remain with the hybrid position as outlined above. It would seem natural, for example, to attribute the absence of nonword priming in amnesics, and the rapid decay of word-completion priming in amnesics, to a deficit in the formation or utilization of episodic traces. If the component of implicit memory that depends on episodic traces is impaired in amnesics, however, it is difficult to explain the acquisition of new associations by amnesics as revealed by indirect tests, and the highly persistent priming effects sometimes shown by amnesics, such as those found in reading geometrically inverted script.

Despite the current theoretical turmoil, a conclusion that can be made with considerable force, based on current task-comparison data, is that human memory is not a monolithic entity, revealing itself in similar ways regardless of the way we choose to test memory. Indirect measures are not simply sensitive memory tests that can reveal "weak" memory traces that evade direct tests—a type of "monolith" theory ruled-out conclusively by those cases in which manipulations produce opposite effects on direct and indirect measures. By contrast, the complex relationships between direct and indirect measures suggest that memory is multifaceted and highly versatile. As our sophistication in interpreting such relationships evolves, we can expect increasingly rich characterizations of the interplay of mental representations and processes that we call "memory."

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